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Musculoskeletal ultrasound

- for diagnostics and treatment guidance in
the orthopaedic outpatient care

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**Karolinska
Institutet**

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MUSCULOSKELETAL ULTRASOUND - for diagnostics and treatment guidance in the orthopaedic outpatient care

THESIS FOR DOCTORAL DEGREE (Ph.D.)

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**To my beloved parents – my father and my late mother –
who provided me with confidence and endurance.**



CONTENTS

1	Introduction	1
1.1	History of medical ultrasound	1
1.2	Physics of ultrasound	2
1.3	Ultrasound technique and modalities	3
1.4	Sources of error - artefacts	5
2	Background.....	7
2.1	Musculoskeletal ultrasound imaging.....	7
2.2	Definitions	8
2.3	Imaging modalities.....	9
2.4	US scanning procedure	10
2.5	Sonographic findings in tendons	10
2.6	Documentation.....	13
2.7	US guided treatments methods	13
3	Aims of the thesis	15
4	Material and Methods	17
4.1	Subjects.....	17
4.2	Study designs	17
4.3	Inclusion and exclusion criteria.....	18
4.4	Equipment	18
4.5	Diagnostics	19
4.6	Treatment methods.....	22
4.7	Outcome measures	26
4.8	Statistical methods	29
5	Summary of papers	31
5.1	Paper I.....	31
5.2	Paper II	33
5.3	Paper III.....	35
5.4	Paper IV	38
6	Discussion.....	41
6.1	General discussion	41
6.2	Evaluation of US findings in tendinopathy	41
6.3	Outcome interpretations.....	43
6.4	Correlation US findings vs clinical symptoms	47
6.5	Sonography - by whom?.....	48
6.6	Strengths and limitations.....	49
6.7	Future research and developments	50
7	Conclusions	51
8	Acknowledgements	53
9	References	55
10	Appendix 1-5	63
11	Papers I-IV.....	65

ABSTRACT

Ultrasound (US) has shown to be of great value in diagnostics and treatment of injuries and chronic pain disorders of the musculoskeletal system. Today, it is considered to be a suitable method when investigating superficially located tendons. Another exciting field of application is the use of US for guidance of different invasive treatments. Traditionally, most diagnostic imaging have been performed at the radiologic departments but the interest for the technique at different care units, including orthopaedic out-patient clinics, has increased. The whole idea and design of this thesis is based on the use of US in an out-patient orthopaedic/sports medicine clinic, in contrary to the traditional use of US.

The general purpose of this thesis was to highlight and evaluate the use and accuracy of US - for **diagnostics, treatment guidance, and evaluation of treatment results** regarding some of the most common musculoskeletal overuse injuries and pain disorders. All patients participating in the studies of this thesis were referred to the Capio Artro Clinic, Stockholm, Sweden with chronic disabling pain in either the Achilles tendon (AT), the patellar tendon (PT) or in the rotator cuff of the shoulder.

In **study I** the main purpose was to assess the inter- and intra-observer reliability in measures of tendon thickness and in the use of a 4-graded evaluation score for US findings. Twenty-eight consecutive patients suffering from chronic painful Achilles- or patellar tendinosis were included. The reliability for measures of distance was found to be high. *Inter*-observer reliability concerning evaluation of neovascularization was moderate to strong, and poor to moderate concerning structural changes. *Intra*-observer reliability was moderate to strong for evaluations of both tendon structure and neovascularization.

The aim of **study II** was to evaluate and compare the clinical results and the US and colour Doppler (CD) findings after treatment of patellar tendinopathy/jumper's knee, using US/CD guided sclerosing injections or US/CD guided arthroscopic shaving, respectively. Forty-three patients with a total of 57 treated tendons were included in this medium-term follow-up study. In the group treated with US/CD guided arthroscopic shaving the mean thickness of the proximal PT had decreased significantly from baseline to endpoint. Tendon improved significantly, and there was significantly less neovascularization at the short term follow-up compared to baseline, in both treatment groups.

In **study III** we evaluated the accuracy of office-based US imaging of rotator cuff tears, performed by a biomedical technician, using arthroscopic surgery as reference method. A secondary aim was to evaluate the differences in the diagnostic value between US imaging in connection to the clinical examination, and the regular concept with MRI performed several weeks prior to the clinical examination. Eighty-two patients underwent all three examination modalities; MRI, US and arthroscopy. Regarding full-thickness tears, including all tendons of the cuff, US showed a sensitivity of 85%, a specificity of 91% and an accuracy of 90%. Based on evaluations of the supraspinatus tendon alone US showed a sensitivity of 100%, a specificity of 89% and an accuracy of 94%.

The aim of **study IV** was to present the short term interim results (6 months) of a new ultrasound and colour Doppler-guided mini-invasive surgical treatment method on chronic painful midportion Achilles tendinopathy, in comparison with the results of eccentric calf muscle training (ECC) and sclerosing (Polidocanol) injections.

Thirty-four patients with chronic painful AT (n=42 tendons) were enrolled in this randomized controlled study. All treatment methods led to clinical improvements. Patients treated with ECC reported less pain and were more satisfied with the treatment result at the follow-up 6 months after the start of the treatment when compared to the other two treatment methods.

Conclusions:

The modified, 4-graded, Öhberg score was found to be a useful and reliable instrument when evaluating status and progress of Achilles and patellar tendon tendinosis.

Using the Öhberg score we could detect a remodelling and a sonographically more normal PT after successful treatment of jumper's knee with US/CD guided arthroscopic shaving compared to US/CD guided sclerosing injections. Both treatment methods rendered good and equal clinical results at medium 4 years after treatment. However, US/CD guided arthroscopic shaving showed a significantly faster return to sport activity, and patient satisfaction could be noticed at an earlier point.

Office-based US imaging of the shoulder, performed by a trained biomedical technician, showed a sufficient accuracy in detecting significant rotator cuff tears. When identifying those injuries the diagnostic value of US imaging performed in connection to the clinical examination was higher than the MRI performed several weeks prior to the examination.

The US/CD guided mini-invasive surgical treatment, for midportion Achilles tendinosis showed a faster clinical improvement than sclerosing injections. In the short-term perspective the ECC seems to lead to the best result. However, the US/CD guided surgical treatment might be a more effective treatment for patients with difficulties in tolerating the uncompromising eccentric training program.

KEYWORDS: accuracy, diagnostic imaging, rotator cuff tears, tendinopathy, ultrasound, Öhberg score

SVENSK SAMMANFATTNING

Ultraljud (UL) har visat sig vara till stor hjälp vid diagnostik och behandling vid olika muskuloskeletala skador och smärttillstånd. Idag anses metoden vara den mest lämpliga för undersökning av ytliga senstrukturer. Ett annat spännande användningsområde med stor potential är vägledning av olika invasiva behandlingsmetoder. Av tradition har muskuloskeletala bilddiagnostik i huvudsak utförts på radiologiska kliniker men UL metodens potential har ökat intresset för metodiken bland de kliniska specialiteterna. Detta gäller speciellt kliniker med idrottsmedicinsk/traumatologisk inriktning och ur ett dylikt perspektiv har hela idén och utformningen av denna avhandling utvecklats.

Det övergripande syftet med denna avhandling var att belysa och utvärdera användandet av UL, på en klinik med idrottsortopedisk inriktning för **diagnostik, vägledning av behandling** och **utvärdering av behandlingsresultat** avseende några vanliga överbelastningsskador och smärttillstånd. Samtliga patienter ingående i denna avhandling var remitterade till Capio Artro Clinic, Stockholm, och inkluderades fortlöpande vid kronisk smärta i hälsena, knäskålssena eller axelns rotator cuff.

Syftet med **studie I** var att utvärdera tillförlitligheten avseende mätning av sen-tjocklek och kvalitativa bedömningar av UL fynd med hjälp av en 4-gradig skala (s.k. modifierad Öhberg score). Tjugoåtta patienter med kronisk smärtande hälsena eller knäskålssena, inkluderades. Vi kunde konstatera att tillförlitligheten avseende mätningar av sen-tjocklek var hög. Korrelationen mellan olika bedömare utföll som måttlig till stark avseende utvärdering av kärlinväxt i senorna och svag till måttligt avseende utvärdering av strukturförändringar i senorna. Tillförlitligheten var måttlig till stark avseende både kärlinväxt och strukturförändringar när samma bedömare upprepade sin bedömning.

I **studie II** var syftet att, i en långtids uppföljning, utvärdera och jämföra det kliniska resultatet och UL fynd efter behandling av "hopparknä", med antingen UL väggledda skleroserande injektioner eller UL väggledd artroskopisk kirurgi. Totalt 43 patienter (57 behandlade senor) inkluderades i studien. I gruppen behandlad med UL väggledd artroskopisk kirurgi hade senornas medel tjocklek minskat signifikant jämfört med före behandling. En signifikant förbättring av senstrukturen kunde ses i båda grupperna liksom en signifikant minskning av kärlinväxt, jämfört med före behandling.

Syftet med **studie III** var att utvärdera precisionen i en UL undersökning avseende senskador i axelns "rotatorcuff", utförd av en biomedicinsk analytiker, med artroskopisk kirurgi som referens metod. Dessutom ville vi utvärdera det diagnostiska värdet av en UL undersökning utförd i direkt anslutning till den kliniska undersökningen i jämförelse med en magnetkamera undersökning (MR) som hade utförts flera veckor innan läkarbesöket. Åttiotvå patienter genomgick all tre undersökningar; UL, MR och artroskopi. UL visade en sensitivitet på 85%, specificitet på 91% och precision på 90% avseende genomgående rupturer, vid inräknandet av alla senor. UL av endast supraspinatussenan visade en sensitivitet på 100%, specificitet på 89% och precision på 94%.

I **studie IV** var syftet att presentera en ny UL väggledd mini-invasiv kirurgisk metod avseende mittportion hälsenetendinos, tillsammans med korttidsresultat i jämförelse med excentrisk träning (ECC) och UL väggledda skleroserande injektioner.

Trettiofyra patienter med kroniskt smärtande hälsenor inkluderades i en randomiserad kontrollerad studie. Alla tre behandlingsmetoder resulterade i en klinisk förbättring men patienter som genomgått ECC angav mindre smärta och var mer nöjda med resultatet vid uppföljningen 6 månader efter start av behandling jämfört med de andra två behandlingsmetoderna. Resultatet av den nya kirurgiska metoden var bättre än resultatet av skleroserande injektioner.

Slutsats:

Den modifierade versionen av Öhberg score kan anses vara ett tillförlitligt instrument för utvärdering av status och progress gällande överbelastningsskador i häl- och knäskålssenor.

Med hjälp av detta utvärderingsinstrument kunde vi med UL registrera mer normala knäskålssenor efter framgångsrik behandling av smärta vid hopparknä med UL-vägledd artroskopisk kirurgi jämfört med senor som behandlades med skleroserande injektioner. Båda behandlingsmetoderna visade bra och likvärdiga kliniska resultat, ca 4 år efter behandling. Patienter behandlade med UL vägledd artroskopisk kirurgi kunde återgå i idrotts- och motionsaktivitet snabbare och uttryckte tidigare i förloppet tillfredsställelse med behandlingen, jämfört med patienter behandlade med skleroserande injektioner.

Validiteten avseende diagnosticering av skador i axelns senor visade sig vara tillfredställande då den utfördes av en biomedicinsk analytiker på en ortopedmottagning. Det diagnostiska värdet av UL undersökningen, utförd i direkt anslutning till den kliniska undersökningen, var större än för MR som hade utförts flera veckor innan den kliniska undersökningen, när det gällde att identifiera dessa skador.

UL-vägledd mini-invasiv kirurgi åstadkom snabbare klinisk förbättring för patienter med mitt-portions hälsenetendinos än skleroserande injektioner. På kort sikt förefaller dock ECC ge den bästa effekten. Den UL vägledda kirurgiska metoden kan emellertid vara en mer effektiv behandlingsform för patienter med svårighet att klara det krävande rehabprogrammet.

LIST OF SCIENTIFIC PAPERS

- I. **Evaluation of Achilles and patellar tendinopathy with greyscale ultrasound and colour Doppler - using a four-grade scale.**
Kerstin Sunding, Martin Fahlström, Suzanne Werner, Magnus Forssblad, Lotta Willberg. Knee Surg Sports Traumatol Arthrosc. 2014 Sep 6.
- II. **Sclerosing injections and ultrasound-guided arthroscopic shaving for patellar tendinopathy: good clinical results and decreased tendon thickness after surgery - a medium-term follow-up study.**
Kerstin Sunding, Lotta Willberg, Suzanne Werner, Håkan Alfredson, Magnus Forssblad, Martin Fahlström. Knee Surg Sports Traumatol Arthrosc. 2014 May 6.
- III. **Office-based ultrasound imaging of rotator cuff tears – the accuracy when performed by a biomedical technician specialized in musculoskeletal ultrasound.**
Kerstin Sunding, Leif Hansson, Staffan Bremmer, Suzanne Werner, Magnus Forssblad, Martin Fahlström, Lotta Willberg. In manuscript
- IV. **Treatment of midportion Achilles tendinosis: Ultrasound-guided mini-invasive surgery, Sclerosing injections or Eccentric training - a randomized controlled, pilot study.**
Kerstin Sunding, Martin Fahlström, Magnus Forssblad, Suzanne Werner, Lotta Willberg. In manuscript

LIST OF ABBREVIATIONS

AP	anteroposterior
AT	Achilles tendon
BMI	body mass index
BT	Biomedical technician
CD	colour Doppler
CI	confidence interval
cm	centimetres
CSA	cross sectional area
CV	coefficient of variance
dB	decibel
ECC	eccentric calf muscle exercise
FTT	Full thickness tear
IQR	inter quartile range
ISP	infraspinatus tendon
JK	jumper's knee
Kg	kilogram
LBT	long head of biceps tendon
MHz	megahertz
mm	millimetres
MRI	magnetic resonance imaging
PD	power Doppler
PT	patellar tendon
PTT	partial thickness tear
RCT	randomised controlled trial
SA/SD	subacromial/subdeltoid bursa
SD	standard deviation
SPSS	Statistical Package for the Social Sciences ® - statistical program
SSC	subscapular tendon
SSP	supraspinatus tendon
THI	tissue harmonic imaging
US	ultrasound/ultrasonography
VAS	visual analogue scale
VISA-A	the Victorian institute for sport assessment – Achilles tendon questionnaire
VISA-P	the Victorian institute for sport assessment – patella tendon questionnaire
X-ray	plain radiography
2D	two dimensional (imaging)
3D	three dimensional (imaging)

1 INTRODUCTION

1.1 HISTORY OF MEDICAL ULTRASOUND

There is more than one story telling us about who discovered the ultrasound (US) technique and as for all technical discoveries and inventions, the development was carried out by many different individuals and teams from all over the world. Those individuals and teams consisted of highly engaged engineers, physicians and physicists, bringing their own unique knowledge and interest into the work.

The Italian biologist Lazzaro Spallanzani demonstrated in 1794 that bats navigate with the help of echo from high frequency sound. His discovery started the acceleration of the development of various use of high frequency US. Around 1820 Jean-Daniel Colladon, a Swiss physicist, studied the spreading of sound under water (in Lake Geneva) and he could determine the velocity of sound in water (1435 m/s). During the second half of the 19th century, sound waves were for the first time described as a mathematical equation in a famous thesis - "the Theory of Sound" - published in 1877 (Macmillan & Co) by John William Strutt (Baron Rayleigh) in England. His work became an important foundation for future development in the field of modern acoustics. [1, 2]



The breakthrough in the progress of high frequency US took place at the end of the 19th century with the discovery of the *piezoelectric effect*. The first demonstration of the piezoelectric effect was performed in 1880 by the French physicist Pierre Curie and his brother Jacques. They found that when they applied a mechanical pressure on certain crystals (e.g. the Rochelle salt), an electric potential was produced. A year later the French physicist Gabriel Lippman (Nobel Prize awarded in 1908) showed, in contrast, that if the same kind of crystal was exposed to an electric pulse, that energy was transduced into mechanical energy, producing a pressure wave - a sound wave. Since then, this inverse piezoelectric effect has been used when producing ultrasonic sound waves. [1]

Thirty-five years later, around 1915, the French professor and physicist Paul Langevin developed the first sonographic image and he and his co-workers used that knowledge to create an ultrasonic submarine detector. Later, underwater sonar detection systems were developed and used to navigate submarines in World War I. The success of those projects opened a great interest in the development of different piezoelectric materials and devices. In 1942, Karl Theo Dussik, an Austrian neurologist/psychiatrist and his brother Friederich, were the first ones to try the US technique for medical imaging, partly inspired by the SONAR technique (Sound Navigation and Ranging) of measuring distance under water. After the World War II an extensive technical development started, especially in the United States and in Japan. This also included the study of US for medical imaging. [1]



Christian Doppler
(1803-1853)

Parallel to the discovery of the high frequency sound, the *Doppler-effect* was described by the Austrian physicist Christian Johann Doppler. In a paper, published in 1842, he studied the stars and found that the colour of the starlight differed between a star moving towards the earth and a star moving in the opposite direction. In the same way the pitch of a sound wave changed depending on how the source was moving in relation to the observer. This effect is used with radar waves to measure the speed of moving objects. Since the 1960s it has been available for use in the medical field to measure the velocity of blood flow. In 1975, Marco Brandestini was the first one to describe the *multi-gated Doppler*. This technique made it possible to produce colour flow images (Brandestini 1978).

An important event in Europe was the development of the first *reflectometer* for medical use, by two Swedish scientists Hellmut Hertz and Inge Edler in 1953. They used the reflectometer to create one dimensional images of a heart – in vitro. In the early 60s the American radiologist Marvin Ziskin, became a pioneer when using US for prenatal diagnostics. Still, these two medical specialties, Cardiology and Obstetrics, are the most frequent users of US in the medical field. The clinical use of US imaging for musculoskeletal diagnostics started in the early 1980s. Since then US gradually has gained terrain to be one of the leading musculoskeletal imaging modalities. Today it is the most practical method capable of dynamic imaging, i.e. simultaneous morphological and functional imaging. [1]



Inge Edler and Hellmut Hertz

1.2 PHYSICS OF ULTRASOUND

Sound comprises of energy that affects a substance so that the particles of a media, by turn, is compressed and separated from each other. A sound wave can be described as a sinus curve (figure 1.2.0). The intensity of the sound depends on the difference in pressure between areas with high compression and areas with low compression. This difference in pressure, the amplitude of the sinus curve, is expressed in decibel (dB). The distance between two areas with high compression in a sound wave describes a wave-length, expressed as lambda (λ). The number of wave-lengths passing a given point every second is described as the frequency (f) of the sound and is expressed in Hertz (Hz). The velocity (c) of the sound-wave can simply be described with the following equation:

$$c = f \times \lambda$$

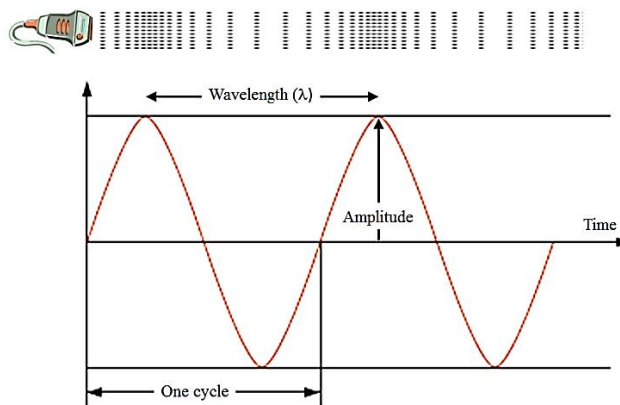


Figure 1.2.0.

US is acoustic waves with a frequency above 20 000 oscillations per second (20 kHz), which is above the limit of human hearing (~ 20-20 000 Hz). In the medical field, a frequency range of 2 – 20 MHz is used for diagnostic imaging. Via the US transducer a piezoelectric crystal is used with the capacity to convert an electric signal to a mechanical energy, and the opposite, to convert a mechanical energy to an electric signal. Thus, it can work both as a transmitter and a receiver. Modern US transducers contain a large amount of piezoelectric crystals, tightly placed in a row. When exposed to an electric pulse the crystals send out short pulses (~1μs) of sound waves. Between these emitted pulses the transducer is working as a receiver for about 99% of the time. The sequence of emitting and receiving is repeated in a frequency of about 1000/sec. This action of the US device is called *pulse echo imaging*. The sound waves emitted into the tissue are reflected by the body structures, creating echoes. [3, 4]

Since US uses non-ionizing mechanical sound waves, which need a physical medium for transmission, it cannot pass through air or tissues containing air. Other imaging modalities, like plain radiography (X-ray), magnetic resonance imaging (MRI) and computed tomography (CT) uses electromagnetic waves, capable of spreading almost anywhere. [4]

The US wave is continuously influenced due to the *acoustic characteristics* of the specific body tissue which it passes through. The velocity of the sound wave is dependent of the density of the media, where a high density tissue means a higher sound velocity than one with a lower density. In terms of acoustics, the soft tissue of the body is considered to be similar to a fluid, and a mean value of 1540 m/sec is used as a general unit value of the sound velocity when using US in the medical field. [3, 4]

Acoustic impedance (Z) or characteristic impedance is describing the resistance, or difficulties for the particles in a media to move, and is depending on the property/density (ρ) of the media. The intensity of the reflected echo when passing the interface between two different media - in this case the body tissues - is determined by the equation: $Z = \rho \times c$. For instance, at the boundary between fat tissue and kidney tissue less than 1% of the sound wave is reflected - this is sufficient for detection with an appropriate transducer - and the remaining sound waves passing through can give rise to new echoes from deeper situated tissues. [3]

The intensity of the sound wave is declining as the penetration depth increases. The most important physical explanations for this *attenuation* or fading are; reflection, refraction or absorption.

Reflection – refers to a change in direction of the sound wave. When sound reaches the interface between two media at an angle of 90° , parts of the wave front will “bounce” and return to the transducer.

Refraction – refers to a change in direction of propagation of the sound wave. When sound passes the interface between two media at an angle other than 90° , it will bend from its original direction.

Absorption - refers to when a media takes in the sound energy instead of reflecting it. Part of the absorbed energy is transformed into heat and part is transmitted through the absorbing media. In terms of US imaging, the energy transformed into heat is considered to be “lost”.

Thus, when the US wave meets a sudden change in the acoustic characteristics of the tissue – i.e. at a boundary between tissues with different density - a certain part of it is reflected, but a major part of the beam continues through the interface and can give rise to echoes from deeper structures. Some of the waves are refracted and some are simply converted into heat. [3, 4]

1.3 ULTRASOUND TECHNIQUE AND MODALITIES

The base for all two-dimensional (2D) US images is the brightness modulation (B-mode), where the depth of a spot on the screen corresponds to the time interval from the transmission of a sound pulse to the receiving of an echo, and the brightness of the spot to the strength of the echo. By using a high repetition frequency the images can be extremely fast and continuously updated, giving very close to real-time dynamic images. With grayscale US the structure of the body tissues can be visualized. [3, 4]

Resolution

Several forms of image resolution should be considered when using real time US.

Spatial resolution describes the capacity to separate small adjacent structures in three dimensions: *Axial resolution* (parallel to the US beam), *Lateral resolution* (perpendicular to the US beam) and *Elevational resolution* (within the depth of a slice) and it is measured in units of distance (mm). The US wave length sets the limit of the spatial resolution.

Contrast resolution describes the ability to separate objects with small differences in acoustic characteristics, shown in different shades of grey, also defined as signal-to-noise ratio. Increasing the spatial resolution is meaningless without a corresponding increase in the contrast resolution.

Temporal resolution describes the capacity to separate two close time events, e.g. that an object has moved over time. In medical US, temporal resolution is the same as the frame rate.

A fundamental rule when adjusting the machine setting is that increased transducer frequency (MHz↑) will result in a higher spatial resolution but at the same time a decrease in penetration, and vice versa. Increasing the temporal resolution causes a decrease in spatial resolution. These things are good to have in mind when adjusting the equipment depending on the area of interest. [3, 4]

Tissue harmonic imaging (THI)

It has been shown that the reflecting echoes produced at the deep structures contains sound waves of more than one frequency and some of them could be as high as the double of the emitted frequency. Since those higher frequency sound waves, *harmonic frequencies* are produced deep in the tissue it will only have to travel half the distance and in that way more energy will be left for the US transducer to receive. The THI technique uses this phenomenon which makes it possible to transmit a sound wave with a low frequency to increase the penetration and then receive ("listen") on a higher frequency, which increases the image resolution. THI is frequently used to improve the image contrast and reduce the noise. The harmonic effect is mostly generated in the mid field of the sound beam. Only a small amount of harmonic components are produced in the near field, and in the far field of the sound beam the harmonic components attenuates faster than it is produced. For musculoskeletal use THI has the advantage of giving a very high resolution of tissues located in the depth range between approximately 1 and 3 cm when scanning at a frequency range of 5-14 MHz. However, deeper located tissues are often better shown without the THI. [3, 4]

Doppler

The Doppler-effect is mostly used to detect blood corpuscles in motion. By analysing the difference in frequency between the emitted and the received echo, the so called *Doppler shift*, the blood flow velocity can be determined. With continuous Doppler it is possible to find and determine high velocities, e.g. the maximal flow velocity in a partly obstructed blood vessel, while pulsed Doppler is used to determine the flow in a specific point. With colour or power Doppler (CD/PD), both pulsed Doppler techniques, it is possible to detect hyperaemia or neovascularisation inside a tendon or a muscle and their surrounding tissues.

The CD technique is analysing the frequency shift of the returning echo - the higher blood velocity the stronger the signal - while PD is detecting the energy in the returning echo - the higher amount of blood corpuscles the stronger the signal. The advantage of CD is the ability to show the direction of the flow – typically displayed on the screen in red for one direction and in blue for the opposite. This is not possible with PD, which shows all flow in the same colour regardless of the direction. On the other hand, since PD is not sensitive to the angle of the flow in relation to the US transducer, it is capable of detecting very low flow also when it is directed in 90° to the beam. However, in all the studies included in the present thesis the CD technique was used to evaluate the amount of visible increased blood flow. [3, 4]

Duplex

This modality allows for greyscale 2D-imaging in combination with CD or PD (B-mode and pulsed Doppler). Both modalities are presented simultaneously on the same screen ("duplex") as overlapping images to facilitate interpretations. The Duplex modality is highly applicable in the field of musculoskeletal imaging, where the intention usually is solely to detect increased blood flow, while the velocity of the flow is mostly irrelevant. [3, 4]

1.4 SOURCES OF ERROR - ARTEFACTS

US imaging is afflicted with many different sources of error. It is essential to acquire knowledge in this area to be able to make confident and accurate diagnosis. A basic rule, when there is a doubt about an echo in the image, is that if it disappears when the angle is changed then it is an artefact. Some important sources of error and artefacts commonly occurring in the field of musculoskeletal US are described below. [3, 4]

Anisotropy - Structures evaluated with US are shown most distinct when the emitted sound wave hits the structure in an angle of 90° . Every lap from this angle leads to fewer retrieving echoes and the structure becomes more hypoechoic. This describes a very common artefact called *anisotropy*, which it is important to be aware of. Since some pathological changes in a tendon or ligament also may appear hypoechoic it is important to put some effort in correcting the angle. Anisotropy is shown in both a longitudinal and transversal view, but it occurs when the transducer is angled relative to the long axis of a structure (figure 1.4.0). [3, 4]

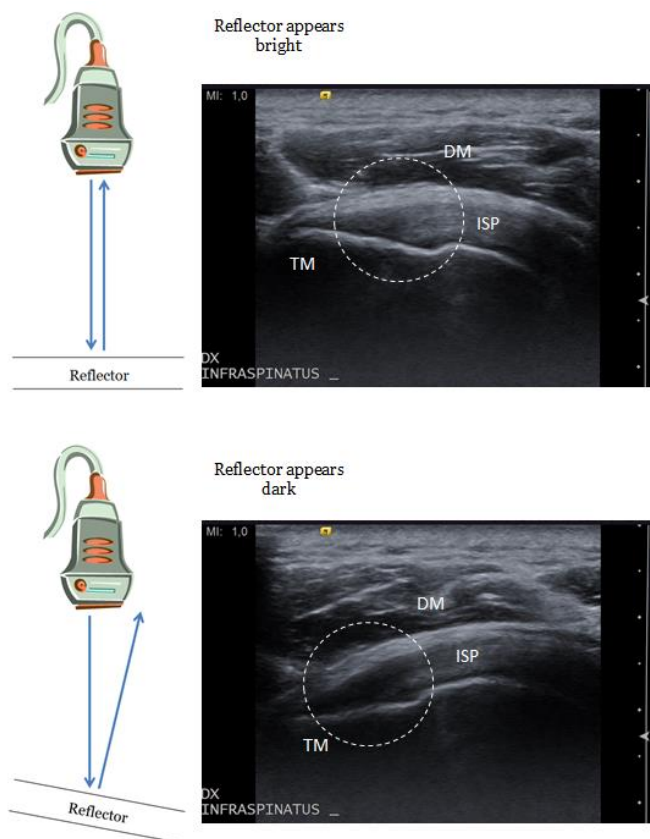


Figure 1.4.0. Upper part showing the infraspinatus tendon scanned in 90° to the tendon fibres, and the lower part showing the same tendon scanned in a lower angle.

Shadowing - The reflection between a soft tissue and air or bone is almost 100%, which gives a very strong echo. Hardly any energy is left of the sound wave to pass through the interface and thus no reflections can be detected from the underlying tissues. This phenomenon, shown as an “empty” black region below the reflecting interface in the image, is described as an *acoustic shadow*. [3, 4]

Acoustic enhancement - a sound wave loses energy (attenuates) on its way through a tissue. The attenuation is less when the sound wave passes through a structure filled with fluid, and therefore more energy is kept. Thus, a tissue beyond a fluid filled structure will look brighter than the tissue beside the fluid. This artefact can be useful since a fluid filled structure can be separated from a hypoechoic mass. [3, 4]

Reverberation (“ringing”) is an artefact that might appear when sound waves are hitting two structures, with high density, located close to each other along the sound beam. In such cases the sound waves can be reflected back and forth, repeatedly, between those high reflecting interfaces before returning to the transducer. Because of the increased time interval for the echo to return, the US equipment will misinterpret the depth of the reflecting structure. This phenomenon will give rise to multiple echoes in the image, below the true echo, a “comet-tail” artefact (figure 1.4.1). [3, 4]

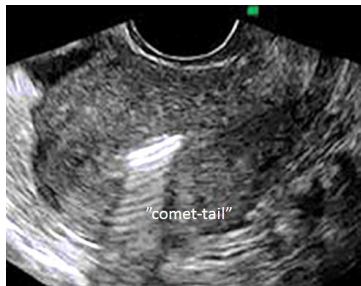


Figure 1.4.1.

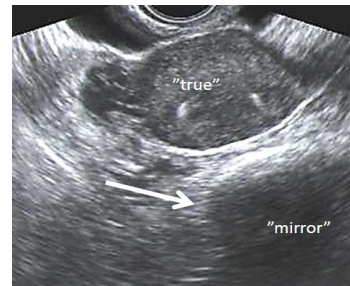


Figure 1.4.2.

Mirror image is another common artefact which can appear if there is a highly reflective surface located deep to the structure of interest. Some of the sound waves are passing through the structure of interest and a strong echo is produced at the deeper surface. This echo is then reflected back to this structure and then again to the deeper surface before turning back to the transducer. The artefact produced resembles a mirror image of the examined structure, shown below the deeply located highly reflective structure (figure 1.4.2). [3, 4]

Eventually, it is important to minimize artefacts from sources outside the US machine, e.g. bright light in the examination room or different barriers around or at the patient. Furthermore, tight clothing and tape or plaster on the skin that might be a hindrance should be removed. A sufficient amount of gel should be applied in order to achieve a uniform contact between the transducer and the skin, and to avoid artefacts due to formation of air bubbles. In some body areas a thickened, outermost layer of the skin - the stratum corneum - can make good imaging difficult because of significant attenuation of the sound waves (Bianchi et al 2007).

2 BACKGROUND

2.1 MUSCULOSKELETAL ULTRASOUND IMAGING

The US imaging technique was available for clinical use before MRI, and for musculoskeletal use clinical attempts were started already in the 1970s. However, for some reason US was lagged behind in this area, possibly due to the development of MRI. In the beginning the MRI technique could offer images with higher resolution than the US technique. This might be one reason why US, temporarily, lost its position in the field of musculoskeletal radiology. Traditionally, most diagnostic imaging of the musculoskeletal system has been performed at the radiologic departments. The radiologists were used to a procedure where they analysed raw data images, collected by nurses or technicians specialised in image projection work. They were also used to evaluate freeze frames, like plain radiograph images (X-ray), to make a diagnosis, which often was done without seeing the patient. This situation has changed a lot, and nowadays radiologists are more engaged in all steps of the imaging procedures, especially within intervention-radiology, and contact with the patients is more common.

In recent years US has recaptured a position in the field of musculoskeletal imaging. However, the greatest revival is not taking place in the radiological departments but rather in different clinical settings, e.g. in rheumatology, physiotherapy and lately also in orthopaedic departments. In Scandinavia, many dynamic and physiologic events of the human body are studied within the scope of clinical physiology, a specialist unit where most examinations includes some level of interaction with the patient. Some examples are US imaging of cardiac and vascular disorders including the use of both spectral and two-dimensional Doppler techniques (colour Doppler). US imaging in these departments are mostly performed by biomedical technicians, with a university degree in US physics and diagnostic imaging technique. In the present thesis all US examinations were performed by a biomedical technician.

US has shown to be of great value in diagnostics and treatment of injuries and chronic pain disorders of the musculoskeletal system. The method has gained terrain also when speaking about time saving and cost effectiveness (Parker et al 2008). This modality is relatively easy to access, both for patients and clinicians, and it can provide images with high spatial resolution as well as real-time dynamic imaging. This can be compared to MRI which, still today, is the diagnostic tool of “first choice” when evaluating injuries in the musculoskeletal system. It is known that, with modern high frequency transducers (10-15 MHz), US can achieve a higher spatial resolution now than the routine MRI (Lee 2012). The resolution of greyscale US is now less than 300 μ m producing one of the highest levels of definition of musculoskeletal soft tissue morphology (Erickson 1997). For instance, fine structures, like secondary fibre-bundles of a tendon, can be depicted with US (Martinoli et al 1993) but not with the routine MRI. One disadvantage is the limited field of view, with linear transducers, and a decrease in penetration when increasing the US frequency. This makes it difficult to get a survey picture to show the relationship to structures adjacent to the tissue of interest, which could increase the risk of underestimating the extent of an abnormality. On the other hand, MRI is rather time-consuming and sometimes its specificity and sensitivity is poor when it comes to investigations of tendon and cartilage injuries. The availability is rather low and patients have to wait several days, sometimes even weeks, for an examination and the cost is rather high. During recent years, a number of studies using the capability of US in orthopaedics have been performed. However, verification of the US technique and methodology in this area still needs to be further studied.

2.2 DEFINITIONS

Echogenicity - This term refers to the ability of a certain tissue to transmit or reflect US waves in relation to the surrounding tissues.

Hyperechoic tissues - Tissues or media with high density is highly reflective and thereby shown relatively bright in the US image, e.g. bony edges and calcifications.

Hypoechoic tissues - Correspondingly, a tissue or media with low density is less reflective and thus relatively dark in the image, e.g. bursa tissue, healthy muscle tissue or a tendinotic region inside a tendon.

Isoechoic tissues - Two adjacent tissues with similar echogenicity can be difficult to separate, and therefore defined to be *isoechoic*.

Anechoic tissues - Low density tissues like blood, joint fluid or cysts are shown as almost black regions in the image and therefore defined as being *anechoic*.

Neovascularization - This term is describing a proliferation of blood vessels or functional microvascular networks in a tissue that in the normal cases contains none or a spare amount of blood vessels. In the present thesis the expression “neovascularization” is used as a general term for all visible blood flow inside a tendon, even though some of the vessels may rather be native vessels with increased blood flow during for example a healing process (Alfredson et al 2006).

Tendinopathy - is a general term for tendon disorders, consisting of disabling pain and swelling in the tendon. This tendon problem is commonly associated with overuse or attrition or trauma (Khan et al 1998b, Maffulli et al 1998, Peers et al 2005). Different diagnoses of tendon problems included in this term are described as follows.

Tendinitis, tendonitis - today considered to be obsolete expressions that have been widely used, assuming that there is a true inflammation within the tendon (Kannus et al 1991, Åström et al 1995, Alfredson et al 1999, Alfredson et al 2003).

Tendinosis - by many researchers considered being a degenerative stage including chronic (>3 months) pain and swelling in a tendon without any acute onset and in US/biopsies visible changes in the tendon structure (Maffulli et al 1998, Khan et al 1999, Peers et al 2005).

Paratendinitis, peritendinitis - a true inflammation in the paratenon (Åström 1995).

Partial rupture – ruptures in minor parts of a tendon, local fibres bundles, could be secondary to a longstanding tendinosis.

Jumper's knee - a chronic painful impairing tendinotic proximal patellar tendinopathy (Willberg 2013).

Acute Achilles tendon rupture - a traumatic diagnosis that generally does not require a diagnostic imaging to be determined. A thorough anamnesis and clinical examination including an evaluation of muscle tonus and Thompsons test are almost always revealing the correct diagnosis.

All the above definitions concerning tendon pathologies have been more widely discussed and described in a recent thesis by Willberg, Umeå University 2013.

2.3 IMAGING MODALITIES

Plain radiography (x-ray) - Since plain radiography produce two dimensional (2D) images it provides less information than the 3D images produced by computed tomography (CT) or MRI. However, a thickening of the Achilles tendon (AT) can be detected when radiological conditions are good (Shalabi 2004). Conventional X-ray is of great value when suspecting skeletal injuries e.g. fractures, degenerative changes, bony spurs, infections or cancer. X-ray is important to confirm architectural variations of the coracoacromial arch with an outlet view of the acromion. Some of these variations e.g. anterior acromial spurs and inferior acromioclavicular osteophytes decrease the volume of the subacromial space which is commonly seen in patients suffering from symptoms of impingement (Bigliani et al 1991).

Magnetic resonance imaging (MRI) - is using magnetic fields and radio waves to produce images of the body. The technique is widely used in hospitals for medical diagnosis and follow-up after treatments without exposure of the body to ionizing radiation. Applications in the musculoskeletal system include spinal imaging, assessment of joint disease and soft tissue abnormalities. When using MRI a common finding in tendinopathies is a local widening and high signal intensity in the affected region of the tendon (Johnson et al 1996; Schmid et al 2002). The differentiation between partial rupture and tendinosis is sometimes difficult when using MRI. However, it has been concluded that MRI can be used as an adjunct to clinical evaluation to study the morphological effects in AT after different treatment interventions (Shalabi 2004). MRI is today the imaging modality of first choice when rotator cuff abnormalities are suspected.

Computed tomography (CT) - Within the field of diagnostic imaging CT is used to portray organs and tissues of a patient in 3D. In addition to the anatomical image it can also visualize organs and tissues with very low density. CT is often used to image complex fractures, especially intraarticular fractures, because of its ability to reconstruct the area of interest in multiple planes with a high resolution (0.2 mm) (Buckwalter et al 2001). It has been concluded that although CT can demonstrate abnormalities within a patellar tendon (PT) reliably, US may assess the pathological process more accurately (Mourad et al 1988). When evaluating patients with shoulder trauma CT is of great value although it gives limited information of the soft tissues (King et al 1999). Today, it is used only in patients with contraindication to MRI, and/or if US or MRI is not available.

Ultrasound - In the area of musculoskeletal imaging the most obvious field of application for US is for diagnostic purposes of overuse injuries. *Tendinopathy*, including many different diagnoses and sites of abnormality, is probably the most common cause for a clinician to ask for an US/CD. Based on the diagnosis and site of tendinopathy, these disorders require quite different treatment strategies. Thus, it is important to be able to separate them. US is suggested to be the superior imaging modality in order to make these distinctions (Warden et al 2007). Studies have shown that US combined with CD or PD leads to a higher sensitivity and specificity in diagnosing Achilles and patellar tendinopathy than when only using the greyscale US (Warden et al 2007). Furthermore, US has shown to be an accurate imaging modality for examination of rotator cuff disorders (Crass et al 1988, van Holsbeeck et al 1995, Teefey et al 2000, de Jesus et al 2009). All the studies presented in this thesis are dealing with tendinopathy at different sites and severity.

2.4 US SCANNING PROCEDURE

When scanning many patients every day it is important to arrange a good environment and working posture in order to avoid overload injuries, which have become rather common among full time sonographers (Mercer et al 1997). Advanced US machines usually generate a lot of heat in the examination room and sometimes installation of an air cooler is necessary.

The transducer should be stabilized on the patient with some fingers or the heel of the imaging hand (Jacobson 2007). This technique makes it easier to keep an optimal pressure against the skin and to make fine adjustments of the image projection. For instance, when adding CD for evaluation of neovascularisation it is important to apply the probe very softly in order to avoid obstruction of the blood flow.

Experienced sonographers usually find an advantage in using standardised projections to be able to compare findings, e.g. between patients or before and after treatments, but also to make sure not to forget any parts of the examination. This is particularly important when evaluating the shoulder where many different parts should be examined. However, it is also valuable to make use of the flexibility of the method by using creative projections to visualise specific structures or dynamic events. This potential factor might be the greatest advantage of this imaging modality.

Dynamic imaging

Some disorders or injuries are more clearly visualized when imaging is performed during motion of a tissue. Dynamic sonography has shown to be comparable with subacromial bursography in displaying bursitis and fluid distensions of the shoulder (Farin et al 1990). During active elevation of the humerus, both laterally and anteriorly, attention is paid to the subacromial/subdeltoid (SA/SD) bursa to see if the bursa is gradually distending and pressed laterally to the SD portion.

Furthermore, subluxation of the long head of the biceps tendon (LBT) can easily be diagnosed while scanning over the bicipital groove during maximal external rotation of the shoulder, to displace the tendon out of the groove (Farin 1996). This diagnose can remain undetected if the shoulder is scanned only in a neutral position. It could also be of value to examine the AT during the performance of a Thompson's test, to make imaging findings more clear, when suspecting a small partial tear.

2.5 SONOGRAPHIC FINDINGS IN TENDONS

The normal tendon

Today, US is considered to be a valid, and probably the most suitable, method when it comes to evaluating superficially located structures such as tendons, for instance AT and PT (Fornage 1986, Martinoli et al 1993, Åstrom et al 1996, Weinberg et al 1998, Khan et al 2003, Peers et al 2003). When evaluating a structure with the use of US, it is sometimes more difficult to state what is normal than to state that something is wrong or abnormal. The appearance of a normal structure has many "faces" and it will take several examinations of the same specific tissue to have passed the learning curve. It is of great importance that tendons are scanned parallel to the fibres in order to avoid *anisotropy*. Generally, normal tendons appear sonographically homogenous. With grey-scale US the tendon structure is seen relatively hyperechoic with linear echoes, in a longitudinal view, representing secondary fibre bundles and the loose connective tissue in between (Kainberger et al 1990, Martinoli et al 1993), see figure 2.5.0. In a transverse view, it appears more spotted or speckled, sometimes described as a honeycomb pattern (Kainberger et al 1990). Results from several studies have provided reference values considering the mean thickness of some specific tendons: the midportion AT (4.5-6,0 mm) (Fornage 1986, Mathieson et al 1988, Koivunen-Niemelä et al 1995, Ying et al 2003), the proximal PT (3.5-5.5 mm) (Kartus et al 2000, Nyland et al 2006, Skou et al 2013), and tendons of the rotator cuff (3.5-5.5 mm) (Cholewicki et al 2008, Karthikeyan et al 2014). The tendon should be assessed completely, down to its distal insertion. Calcific enthesopathy, a common diagnosis, can be missed if the distal insertion has not been evaluated.

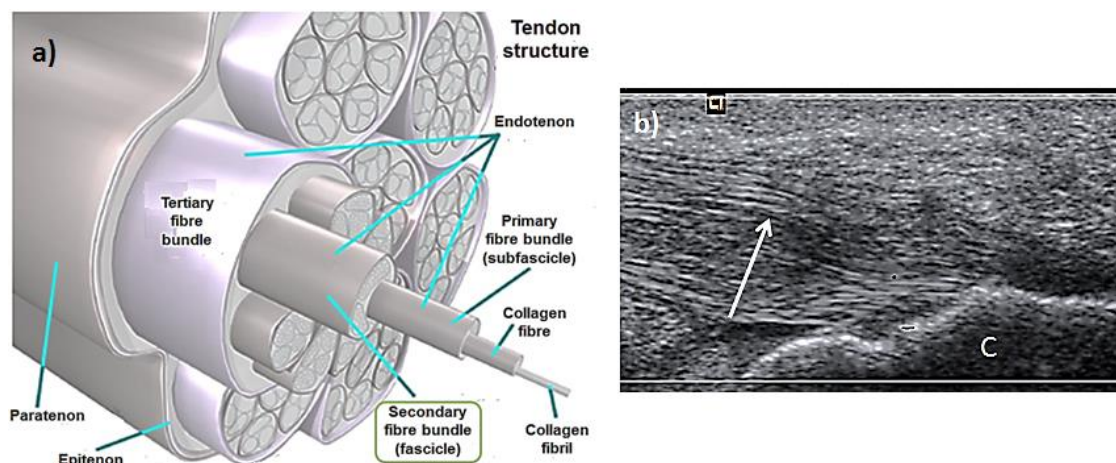


Figure 2.5.0. a) Showing the general organisation of a tendon structure. b) US image of an Achilles tendon at the insertion to the calcaneus (C), clearly picturing *secondary fibre bundles* (arrow).

The blood supply of tendons in general has shown to be mostly longitudinally oriented vessels located in the paratenon and endotenon. Carr and co-workers showed that the paratenon is a highly vascular tissue which contributes to blood supply throughout the whole length of the AT, with three different origins: the osseo-tendinous junction, the mesotendineum and the musculotendinous junction (Carr et al 1989). However, the blood flow in a normal tendon is known to be low. Adding CD or PD to the US examination will not reveal any signs of increased vascularity or blood flow in the majority of normal cases (Öhberg et al 2001). The mid-portion of the AT has shown to have a low number of blood vessels and a low mean percentage area occupied by blood vessels. This might explain the relatively slow healing response and adaptation to change of tendons in general (Josza et al 1997, O'Brien 1997). Furthermore, it has been shown that the actual blood flow is low at the insertion to the calcaneus (Åström et al 1994).

US findings in tendinopathy

Tendinopathy is often associated with some kind of degeneration (Riley 2005). In tendinosis, the tendons show disarrangement of collagen fibres and degeneration in the extracellular matrix combined with increased vascularity (Khan et al. 1999, Maffulli et al. 1999). According to Kainberger and co-workers (1990) all non-artefactual disturbances of a homogeneous tendon structure indicate abnormality. They interpreted that hypoechoic areas, registered with greyscale US, correlate with areas of focal degeneration, seen in immune-histochemical analyses, where the collagen fibres become invisible for the US. The hypoechogenicity in such areas is assumed to be a result of an increase in water stored by proteoglycans (Kainberger et al 1990, Kannus 2000). However, as mentioned earlier, the tendon echogenicity is angle-dependent, and it has been shown that tendons appear hypoechoic when scanned at an angle greater than $2-7^{\circ}$ (Crass et al 1988). This is important to have in mind when interpreting the findings.

Blood flow in a symptomatic tendon has shown to be significantly elevated in the painful area compared to painfree tendons (Åström et al 1994). With US/CD this elevated blood flow is mainly seen inside and outside the ventral part of the AT and, in a similar way, at the dorsal site of the proximal PT, just below the apex patella. In both cases the increased visible blood flow is corresponding to hypoechoic painful/tender areas (Weinberg et al 1998, Öhberg et al 2001, Reiter et al 2004, Alfredson et al 2005a).

According to study findings by Kardouni and co-workers (2013) the prevalence of neovascularization is not related to symptoms in patients with rotator cuff tendinopathy. Consequently, they stated that the presence of neovascularization is not relevant to aid the clinical assessment of this diagnose.

US findings in tendon tears

A complete tear of a tendon is diagnosed when all the tendon fibres are completely disrupted and separated by a hypoechoic gap (figure 2.5.1). In partial tears, a focal hypoechoic defect in the fibrillary echogenicity of the tendon can be seen (Bianchi et al 1994). The role of diagnostic imaging, when examining patients with shoulder pain, is an important guide to make decisions concerning surgical or non-surgical management. One specific reason to examine patients with symptoms of impingement is to determine whether the rotator cuff is intact or not. In a study by van Holsbeeck and co-workers (1995) the criteria used to detect partial-thickness tears of the rotator cuff were (a) a mixed hyper- and hypoechoic focus in the crucial zone of the supraspinatus tendon and (b) a hypoechoic lesion visualized in two perpendicular imaging planes with either articular or bursal extension. When differentiating a full-thickness tear from a partial-thickness tear of a rotator cuff tendon it is helpful to visualise the tendon during motion, i.e. dynamic imaging. A retraction of the muscle-tendon unit indicates a full-thickness tear (Jacobson et al 2004).

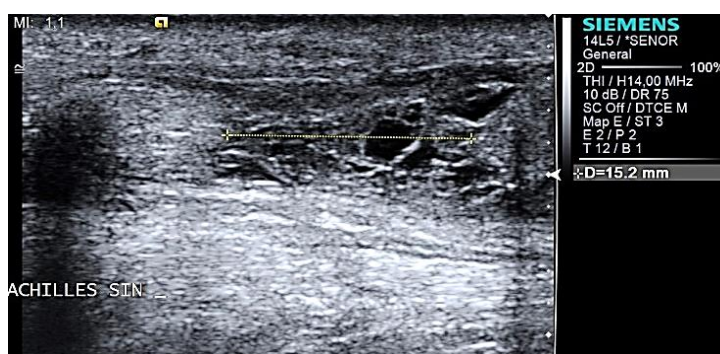


Figure 2.5.1. US image of a total rupture in the midportion of the Achilles tendon, showing a network of granulation tissue between the proximal and distal ends of the ruptured tendon.

Scoring of US findings in tendinosis of the lower limb

Studies in the field of tendon research often evaluate tendon thickness, structural changes and the amount of neovascularization inside the tendons. Several studies of inter-observer reliability, using different methods when evaluating the severity of sonographically visible pathology, have been published (Black et al 2004, Cook et al 2005, Sengkerij et al 2009, Cassel et al 2012). A high inter-tester reliability was found in sonographic assessments of PT tendinopathy when measuring the hypoechoic area in three dimensions (sagittal plane height, axial plane height, and axial plane width) (Black et al 2004). In a previous study measurements of AT and PT anteroposterior (AP) diameters have been suggested to be reliable parameters (Cassel et al 2012). Cook and co-workers (2005) found that tendon vascularity can be reliably estimated using CD, and claimed that tendon vascularity could be used to rate clinical change. Except for measurements of the AP diameter (tendon thickness) these methods seem to be rather complicated and time consuming for clinical use. In 2002 the Öhberg score was introduced in a study investigating midportion Achilles tendinosis (Öhberg et al 2002). In that study the neovascularization in the AT was estimated as 0, 1+, 2++, 3+++, 4++++ according to the appearance of vessels inside the tendons. When there were no visible vessels, the estimation was 0. When there were one or two small vessels, mostly in the posterior part of the tendons, the estimation was 1+. When there were several irregular vessels throughout the tendon, the estimation was 2++ to 4++++. To my knowledge only one investigation, so far, has evaluated the use of a 4-grade scale - similar to the Öhberg score - for neovascularization (Sengkerij et al 2009). In that study power Doppler (PD) instead of colour Doppler (CD) was used though.

In the present thesis a modified version of the Öhberg score (0-3) was tested concerning its reliability in one study and then used for evaluation of treatment results in two other studies.

2.6 DOCUMENTATION

Every US evaluation should be adequately documented by saving images and dynamic clip stores labelled with patient identification, date, and faculty or company identification, initials of the sonographer, as well as name and side of the investigated structure. Most US machines are equipped with an *annotation-system* that can be independently uploaded with practical and useful terminology to make this important part of the imaging process easy. There should be a journal record where the actual imaging findings are described in the first part and its interpretation in a final report. It is desirable that images of both normal and abnormal findings are recorded so that in case of re-evaluating images it becomes obvious that the examination has been adequately performed and no parts have been forgotten. Standardised protocols for documentation of quantitative measures of the images (e.g. distance; length and width or thickness) and qualitative evaluations (structure; echogenicity and vascularisation; colour flow) together with demographic data of the patient is desirable. The protocols used in the different studies of this thesis, concerning AT, PT and tendons of the rotator cuff, are presented in appendix 1-5.

2.7 US GUIDED TREATMENTS METHODS

In the literature it has been reported that US has been used for guidance of punctures, biopsies and injections since the early 1970-ties. At the beginning US-guidance was used in the field of urology and cardiology, e.g. for biopsies of renal masses, for aspiration of cysts and urine bladder and for aspiration of pericardial or pleura effusion (Kristensen et al 1972, Goldberg et al 1973a, Goldberg et al 1973b]. Modern dynamic scanners of today have needle-guide units that can be attached to the head of the transducer. However, experienced sonographer often finds it easier to perform the needle direction and insertion by hand. Holding the transducer in one hand and the needle in the other, gives an opportunity to use the three-dimensional (3D) perception in a triangulation technique (de Haven 1982).

Regions with localized high blood flow, registered with US and CD, inside and outside the painful area in a tendon seem to be of importance for pain and function (Öhberg et al 2001, Alfredson et al 2005a, Hoksud et al 2011). In close relation to the high blood flow sensory and sympathetic nerves have been found in immune-histochemical analyses of biopsies (Forsgren et al 2005, Danielson et al 2008). These findings have led to the development of US/CD-guided treatment methods for chronic painful tendinopathy. In the present thesis, three different US/CD-guided treatment methods have been used; sclerosing injections for Achilles and Patellar tendinosis, arthroscopic surgery ("shaving") for Patellar tendinosis and mini-invasive surgery ("scraping") for midportion Achilles tendinosis.

US/CD-guided sclerosing (Polidocanol) injections, has reported good treatment results in combination with ECC (Öhberg et al 2004, Lind et al 2006). When following the original method, injecting small volumes (maximum 2 ml/treatment) it requires, at mean, 2 treatment sessions with at least three months in-between. In 2007 a mini-invasive surgical procedure was described as a new treatment method for midportion Achilles tendinosis (Alfredson et al 2007). This procedure is based on the same idea as the US/CD-guided sclerosing injection treatment, where neovascularization outside the ventral part of the tendon and accompanying nerve-cells are targeted and the tendon is left untouched. However, this procedure was not per-operatively US-guided. Furthermore, a new US/CD-guided arthroscopic shaving method of patellar tendinosis/jumper's knee was described in 2007 (Willberg et al 2007). In conformity with that method, a new US/CD-guided mini-invasive surgical method has been developed for treatment of midportion Achilles tendinosis. The hypothesis for this treatment was that if one can visualise the pathology in the tendon, per-operatively, by simultaneous US/CD-guidance, the surgical procedure could be minimised to a smaller area. The customary surgical approach concerning chronic pain in AT is still of an open character, bringing on about 6 weeks of immobilisation and 3 months to full loading activity for the patient (Schepss et al 1987, Leach et al 1992, Tallon et al 2001).

3 AIMS OF THE THESIS

The general purpose of this thesis was to highlight and evaluate the use, and the accuracy, of ultrasound as a tool for *diagnostics, treatment guidance* and *evaluation of treatment results* regarding some of the most common musculoskeletal overuse-injuries and pain disorders at an orthopaedic outpatient clinic.

The specific aims of the thesis were:

Study I: ... to assess the intra- and inter-observer reliability for quantitative measures (thickness) and qualitative evaluations (structure and neovascularization) of symptomatic and asymptomatic AT and PT with US and CD using a modified Öhberg score.

Study II: ... to evaluate the sonographic findings and clinical outcome 3–5 years after treatment of patellar tendinopathy with ultrasound-guided sclerosing injections or arthroscopic shaving.

Study III: ... to evaluate the accuracy of office-based US examinations of rotator cuff tears, performed by an experienced biomedical technician. Secondary aim was to evaluate the possible differences in the diagnostic value between US imaging, close to the clinical examination and the regular concept with MRI, performed several months prior to the clinical examination.

Stud IV: ... to present the short term interim results (6 months) of a new US/CD guided mini-invasive surgical treatment method on chronic painful midportion Achilles tendinopathy, in comparison with the results of eccentric calf muscle training and sclerosing (Polidocanol) injections.

4 MATERIAL AND METHODS

4.1 SUBJECTS

All patients participating in the studies of this thesis were referred to the Capio Arthro Clinic in Stockholm because of chronic disabling pain in the AT, the PT or the rotator cuff of the shoulder, and they were consecutively enrolled into the studies.

Study I: Twenty-eight consecutive patients, who were referred to the clinic suffering from chronic painful Achilles tendinopathy (8 males/7 females) or chronic painful patellar tendinopathy/jumper's knee (7 males/6 females), were asked to participate in this study. Both symptomatic (16 AT/13 PT) and asymptomatic (11 AT/13 PT) tendons were included. Three AT, showing signs of recent ruptures, were excluded.

Study II: Forty-five former participants in a prospective randomised study (Willberg et al 2011), and an additional nine patients from a pilot study (Willberg et al 2007), were approached for this study. Out of 54 patients 43 (41 males/2 females) with 57 treated tendons chose to participate in this follow-up study. Thirteen of the eligible tendons were formerly considered as failures (Willberg et al 2011). They were treated with sclerosing injections without satisfying results after a third injection treatment period (Alfredson et al 2005b, Willberg et al 2008) and were offered surgery and were therefore excluded in this study. At endpoint 25 tendons were included in the surgical group and 19 in the injection group.

Study III: One hundred and seventy-two (n=172) consecutive patients referred to the clinic, with symptoms indicating shoulder impingement or rotator cuff pathology, were enrolled in this study. All patients underwent US. Prior to the visit at the clinic most patients (n=136) had been examined with MRI. Within the whole group of patients, 82 (55 males and 27 females aged 30-76 years) underwent all of three examination modalities - US, MRI and arthroscopy. Those 82 patients were included in this study.

Study IV: Thirty-four patients (18 males/16 females) referred to the Capio Arthro Clinic in Stockholm, because of chronic (>3 months) painful AT (n=42) were enrolled in this randomized controlled study, comparing three different treatment methods; ECC, US/CD-guided sclerosing (Polidocanol) injections, and US/CD-guided mini-invasive surgery. The patients included in the present study were clinically diagnosed with a chronic midportion Achilles tendinosis. Eight patients (9 tendons) were excluded before starting the treatment or shortly after the start of the treatment. At the 3rd and 6th month follow-up 28 patients (33 tendons) still remained in the study; 14 tendons were assigned to the ECC group, 11 tendons to the US/CD-guided injection group and 8 tendons to the US/CD-guided surgery group. More basic data are given in "Summary of papers".

4.2 STUDY DESIGNS

This thesis focused on the clinical use of US and CD as a diagnostic imaging modality and as a guiding tool for invasive treatments in the field of tendinopathy. The studies in this thesis are of different designs:

- Study I - a reliability test of an evaluation tool for US/CD findings
- Study II - a prospective follow-up study after US/CD guided treatments
- Study III - a validity test of a diagnostic US/CD imaging method
- Study IV - a randomized controlled pilot study, comparing two different US/CD guided treatment methods

4.3 INCLUSION AND EXCLUSION CRITERIA

General inclusion criteria:

- ≥18 years old
- Ability to understand the study information written in Swedish.

Study I

Inclusion criteria:

- Chronic painful tendinopathy, in midportion AT or proximal PT for more than 3 months. Both symptomatic and asymptomatic tendons without any acute onset of pain were included.

Exclusion criteria:

- Previous surgery or other treatment less than three months ago.
- Pronounced bursitis
- Signs of partial ruptures

Study II

Inclusion criteria:

- Patients with chronic painful patellar tendinopathy, from a previous pilot study evaluating the US/CD-guided arthroscopic shaving method, for patellar tendinopathy /jumper's knee (Willberg et al 2007).
- Patients with chronic painful patellar tendinopathy, from a previous prospective randomised trial (Willberg et al 2011) evaluating treatment with US/CD-guided sclerosing injections and US/CD-guided arthroscopic shaving.

Exclusion criteria:

- Patients that were initially treated with sclerosing injections and later, because of failure after a third injection, were treated with arthroscopic shaving – cross-over patients.

Study III

Inclusion criteria:

- Acute or chronic disabling pain in the shoulder
- Symptoms indicating shoulder impingement or rotator cuff pathology

Exclusion criteria:

- Clinical suspicion of instability problems or adhesive capsulitis, “frozen shoulder”.

Study IV

Inclusion criteria:

- Chronic painful tendinotic midportion Achilles tendinopathy (Willberg 2013) persisting for more than three months (no acute onset!)
- US/CD findings showing increased tendon thickness with hypoechoic regions and ingrowth of neo-vessels into the ventral part of the tendon (Öhberg et al 2001, Willberg et al 2008, Sunding et al 2015).

Exclusion criteria:

- Previous surgery or other treatment less than three months ago.
- Signs of partial ruptures
- Patients treated with anticoagulants
- Allergy to local anaesthetics

4.4 EQUIPMENT

All US-examinations within this thesis were performed using one of two different US-machines: ACUSON Antares™ and/or ACUSON S1000™; Siemens Medical Solutions, both equipped with high-resolution Multi-D matrix transducers - WFX 13-5 (5-13 MHz) or 14L5 (5-14 MHz).

4.5 DIAGNOSTICS

Prior to the US evaluation an independent anamnesis and a clinical examination, including palpation of the region of interest, was performed even if the referring physician has provided an appropriate question formulation.

The Achilles tendon

The AT is usually examined with the patient lying in a prone position with both feet hanging relaxed outside the examination table. Swelling and tenderness during palpation including location should be noted. Thompson's test and tonus of the whole tendon-muscle system as well as the range of motion (ROM) of the ankle joint should be evaluated and compared with the contralateral side (Thompson et al 1962). This can give valuable clues about the severity of an injury, e.g. a partial or total tendon rupture. A standard US examination includes both longitudinal and transversal scanning of the tendon. It is known that the AT is medially twisted (approximately 90°) from the myotendinous junction down to the insertion at the calcaneus, which means that originally posterior fibres become lateral, and lateral fibres become anterior and so on. Some tendons have a "marked medial obliquity" at the midportion (Fornage 1986) and therefore it is necessary to control that the longitudinal projection is cutting perpendicular to the maximal medial-lateral diameter of the tendon by using a transversal view, when measuring the antero-posterior (AP) thickness (figure 4.5.0). In the present thesis, tendon thickness was measured in the longitudinal plane at the midportion of the tendon (~2-6 cm proximal to the superior border of the calcaneus) in the centre of the tendinotic region representing the thickest part of the tendon.

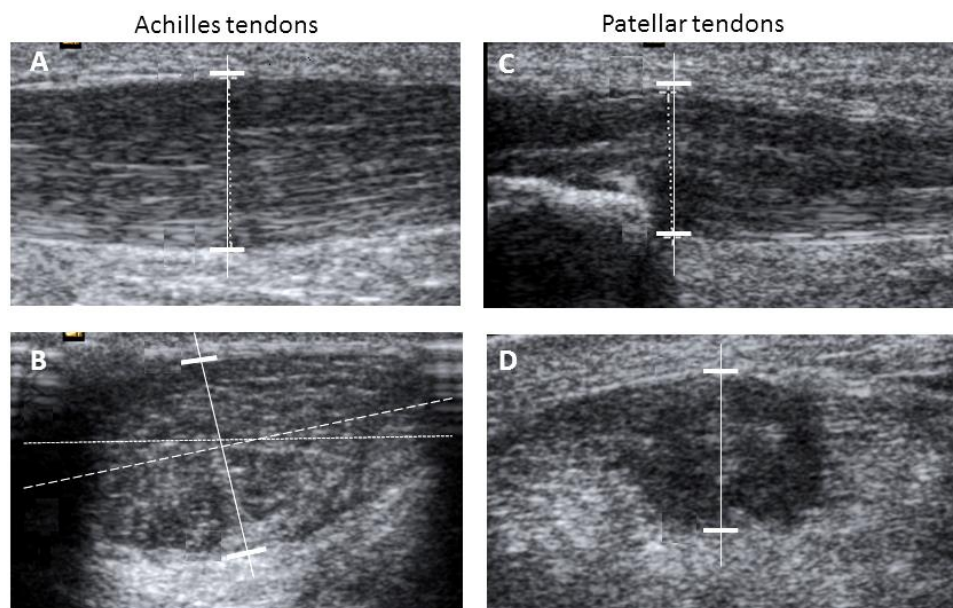


Figure 4.5.0. Showing how and where AP thickness of the midportion AT and the proximal PT were measured. Longitudinal (A) and transverse (B) projection of midportion AT. Longitudinal (C) and transverse (D) projection of proximal PT.

The patellar tendon

The PT is examined with the patient in a supine, neutral position with the knees in extension and the quadriceps muscles relaxed. The tonus of the quadriceps, especially the vastus medialis obliquus (VMO), should be inspected and compared with the contralateral side. Swelling and tenderness from palpation at the proximal insertion to the apex patellae should be noted. Signs of intraarticular pathology should be ruled out with a standard knee joint examination. In the present thesis US evaluations of the PT were performed according to a

routine protocol. Similar to the AT the PT is very easy to depict in its whole, from the proximal attachment at apex patella to the distal insertion on the tibial tuberosity. The diagnosis was confirmed at baseline with US and CD, showing a thickening of the proximal tendon, structural tendon changes and neovascularization inside and outside the dorsal side of the proximal PT.

US and CD registrations were taken in both longitudinal and transversal plane at the whole length of the PT. Tendon thickness (AP distance) was measured in the longitudinal plane at the most proximal part of the tendon in the centre of the tendinotic region representing the widest part of the tendon, as shown in figure 4.5.0. Tendon structure and neovascularization were evaluated according to the modified Öhberg score (Sunding et al 2014).

The rotator cuff

A clinical evaluation of the rotator cuff needs a more comprehensive examination that can be difficult to squeeze into the US examination schedule. However, there are some clinical examination methods that can easily be done before and during the scanning. Look for a side-to-side symmetry in muscle contour of the biceps, supraspinatus and infraspinatus muscles. Dynamic imaging of the subscapularis and infraspinatus tendons of the shoulder could reveal muscle weakness and/or reduced ROM. Such observations are important, especially in cases where imaging is difficult. The sonographic evaluation of the rotator cuff in the present thesis was performed according to a standardized protocol (Vlychou et al 2009). During the US examination the patient was seated on a swivel chair with a low backboard, and the examiner was standing behind the patient. The tendons of - biceps long head (LBT), subscapularis (SSC), supraspinatus (SSP) and infraspinatus (ISP) - were all visualised in both the longitudinal and transversal plane. The tendon of the LBT was examined while the patient was holding the forearm in a supinated position, resting on the thigh, bringing the bicipital groove forward to an anterior position. The SSC and ISP tendons were evaluated dynamically during internal and external rotation with the forearm in supination and the elbow in 90° of flexion. The acromioclavicular joint (AC-joint) was evaluated regarding possible detection of osteoarthritis and sprains. The SSP tendon and the subacromial/subdeltoid bursa (SA/SD) were evaluated dynamically during abduction with the arm in slight internal rotation. Normal as well as pathological findings were documented in a pre-election protocol designed especially for study III (appendix 5).

The diagnostic variables considering the SSP, ISP and SSC tendons were evaluated according to this pre-election protocol considering the degree of abnormality using an ordinal scale:

- 0 = Normal tendon - continuity and homogeneity of tendon tissue (figure 4.5.1).
- 1 = Tendinosis - continuity of tendon tissue with signs of structural changes or increased vascularity.
- 2 = Partial thickness tear (PTT) - discontinuity of tendon tissue, not including the whole depth of the tendon, or focal decrease in tendon thickness (figure 4.5.2).
- 3 = Full thickness tear (FTT) - discontinuity of tendon tissue, involving the whole depth of the tendon or focal atrophy of the tendon arcade, with or without retraction (figure 4.5.3).
- 4 = Complete tear (CT) - absence of tendon tissue in the whole width and depth of the tendon arcade, with some degree of tendon retraction, and/or atrophy of the tendon arcade (figure 4.5.4).

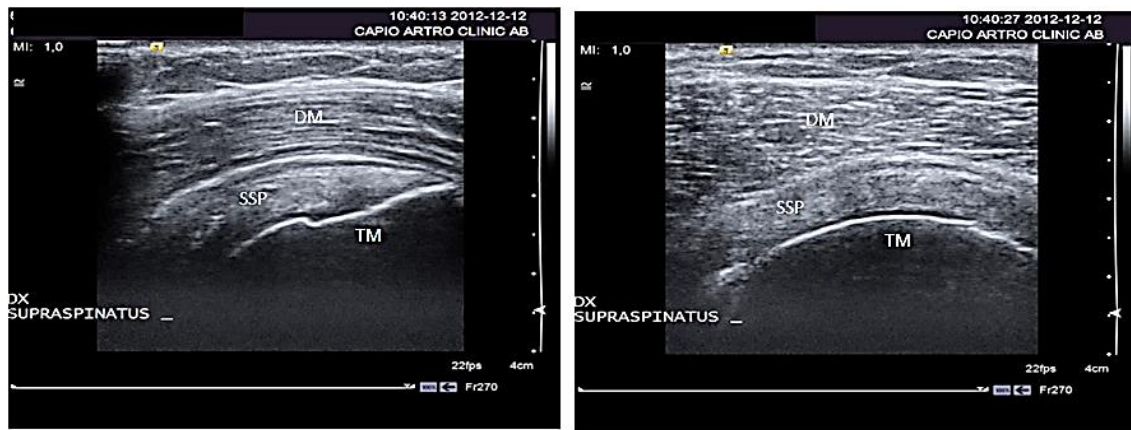


Figure 4.5.1 Longitudinal (left) and transversal (right) view of a normal supraspinatus tendon (SSP) close to the insertion at tuberculum majus (TM). DM=Deltoid muscle.

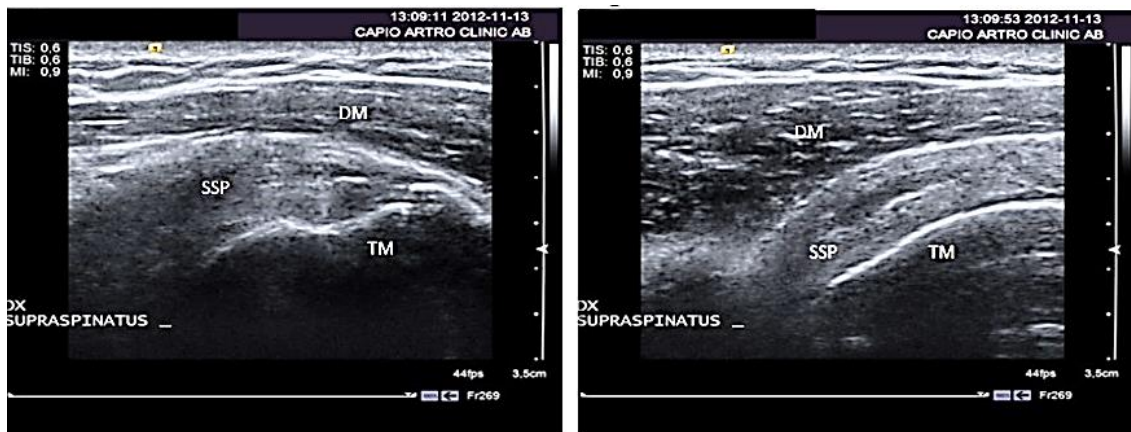


Figure 4.5.2. Longitudinal (left) and transversal (right) view of a partial thickness tear in the centre of the supraspinatus tendon (SSP) close to the insertion at tuberculum majus (TM). DM=Deltoid muscle.

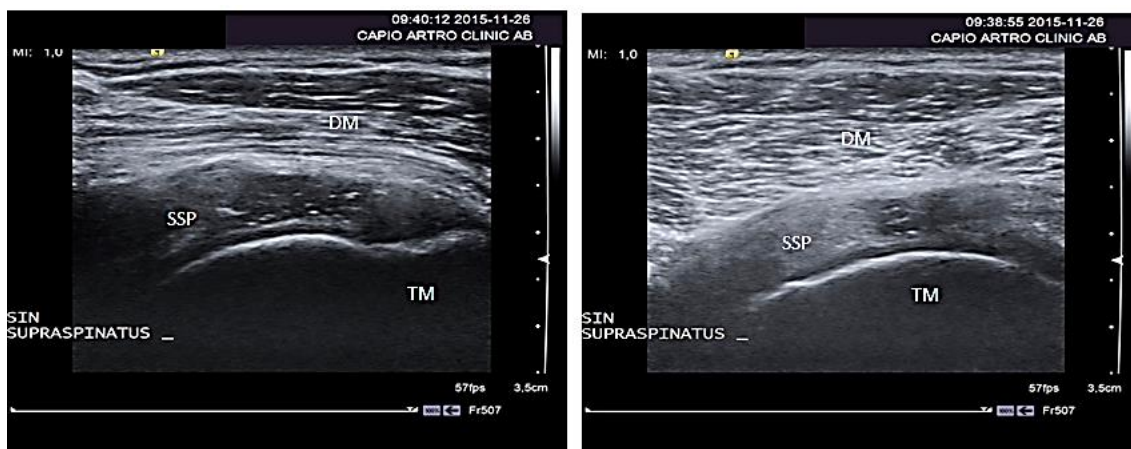


Figure 4.5.3. Longitudinal (left) and transversal (right) view of a full-thickness, partial tear of the posterior part of the supraspinatus tendon (SSP) at tuberculum majus (TM). DM=Deltoid muscle.

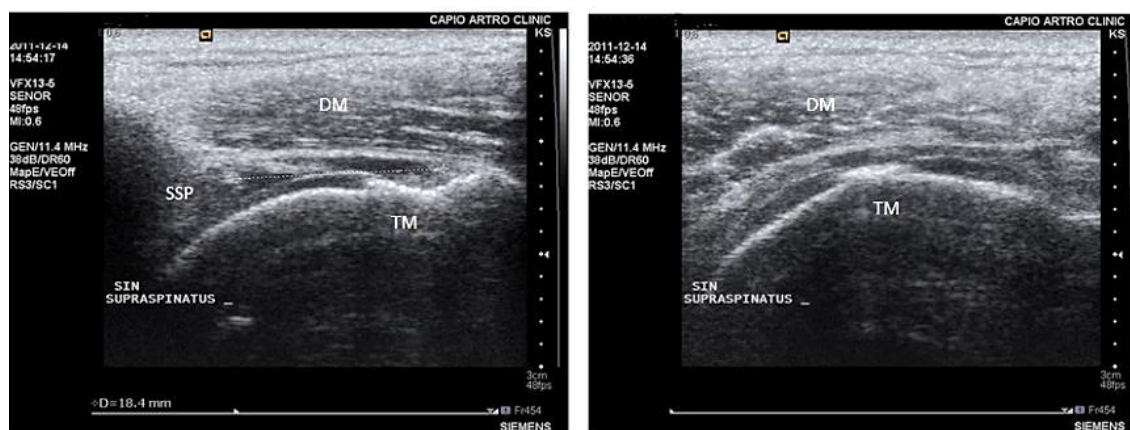


Figure 4.5.4. Longitudinal (left) and transversal (right) view of a complete tear of the supraspinatus tendon (SSP) at tuberculum majus (TM) with retraction of the muscle. DM=Deltoid muscle.

Traumatic injuries of the rotator cuff are most frequently affecting the SSP or the rotator cuff interval. Even if these injuries are rather small they activate a healing process (inflammation) with increased blood flow and swelling of the tendon and surrounding tissues, which make them rather easy to visualise with US.

4.6 TREATMENT METHODS

Eccentric calf muscle training (ECC)

In the pilot study, study IV, one group of patients was randomised and assigned for non-operative treatment of midportion Achilles tendinosis with ECC according to the program described by Alfredson and co-workers in 1998. At the start all patients in this group were instructed by a physiotherapist how to perform their eccentric exercises and they were also provided with written instructions. The regimen included ECC 2 times daily (3 x 15 reps), 7 days/week, for 12 weeks, with the knee extended as well as slightly flexed (Alfredson et al 1998).

US/CD-guided sclerosing injections

This treatment method was used in study IV for treatment of midportion Achilles tendinosis. Furthermore, it had been used for treatment of proximal patellar tendinosis of the patients participating in study II, a mid-term follow up study. The goal of using US/CD-guided sclerosing injections was to target the painful area in the tendon and chemically destroy the ingrowing neo-vessels that are assumed to play a role in terms of pain in patients with tendinosis (Öhberg et al 2002, Alfredson et al 2003, Cook et al 2004). Injections of the sclerosing substance Polidocanol, 5 and 10 mg/ml, have previously showed promising clinical results with no side effects (Öhberg et al 2002, Alfredson et al 2003, Alfredson et al 2005a, Hoksrud et al 2006, Willberg et al 2008).

The injection is performed dynamically with the use of high resolution greyscale US and with the aid of CD or PD to find the entrance of the vessels into the tendon. Many studies in the field of tendon research use PD when investigating the presence of neovascularization inside the tendon tissue. In the studies of the present thesis CD was used for guidance. CD makes it possible to observe changes in flow directions inside the tendon when closing communicating vessels, from the effect of the sclerosing agent, which is not possible using PD. During US/CD-guided sclerosing injections the transducer is held in a longitudinal projection over the tendon, parallel to the tendon fibres, visualizing the area of local neovascularisation at the deep side that corresponds to the tenderness of the tendon (figure 4.6.0). Polidocanol 5 mg/ml has been suggested to be used as the sclerosing agent (Öhberg et al 2002, Willberg et al 2008, Conrad et al 1995, Winter et al 2000). The active substance is an aliphatic non-ionised nitrogen free surface anaesthetic which has a local anaesthetic

and sclerosing effect on the intima media of the vessels causing thrombosis (Guex et al 1993).

Before the treatment, the skin should be disinfected using a solution of chlorhexidine and alcohol. It is preferable to cover the skin with a sterile paper-cover with a hole exposing only the region of interest. The injection is always done from the medial side of the AT to minimise the risk of contact with the sural nerve, while injection of the PT can be performed from either the lateral or the medial side. Only the transverse vessels at the deep side of the tender and hypoechoic area of the tendon should be targeted. The longitudinal vessels with increased blood flow should not be obstructed since those probably represent native vessels activated in a healing process (Alfredson et al 2006). A correct injection should result in immediate closure of the targeted vessels. In our experience, a total of 2 ml is generally a sufficient volume to inject at a single treatment session and the treatment should be repeated, at the earliest, after 6-8 weeks and preferably after at least 12 weeks, if the symptoms stay unchanged together with remaining transversal ingrowth of neo-vessels. After completing the injections a light compression bandage should be applied for 24 hours. Then the patient was allowed walking but not training the affected tendon during the first 10-12 days following the treatment.

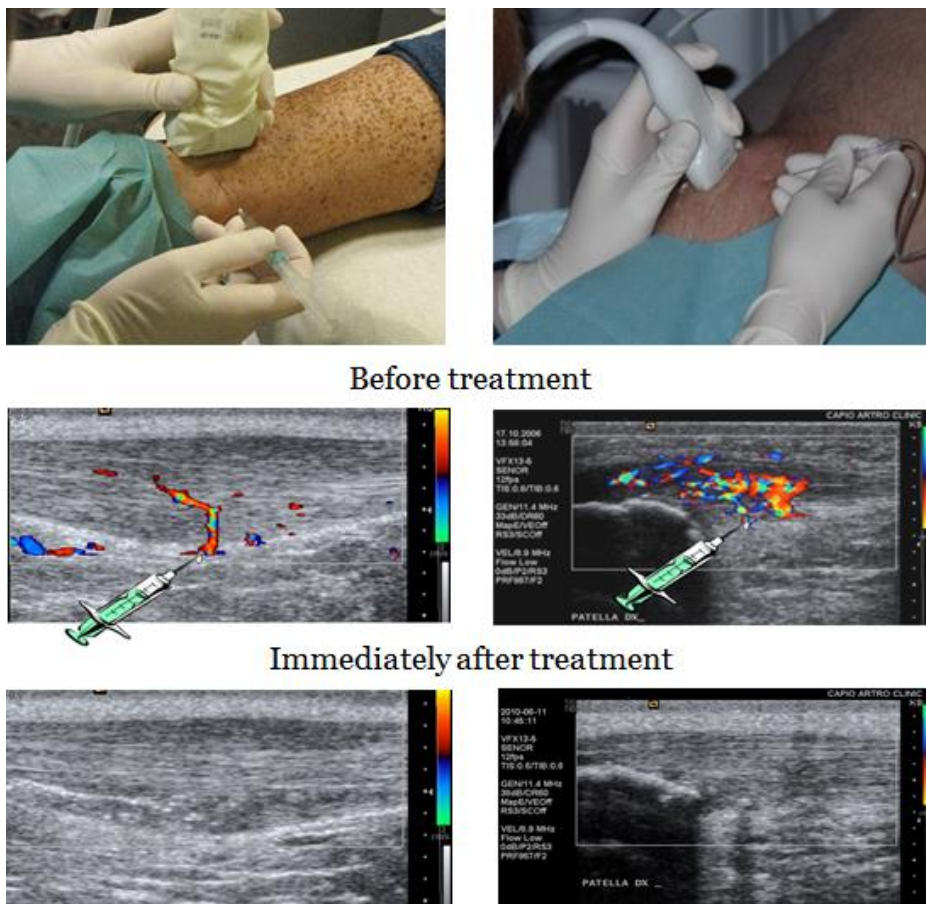


Figure 4.6.o. Procedure and imaging during US/CD guided sclerosing injection treatment of midportion Achilles tendinosis (left column) and proximal patellar tendinosis (right column).

US/CD-guided mini-invasive surgery (“scraping”)

This method was used for the first time, in study IV of this thesis, for treatment of chronic painful *midportion Achilles tendinosis*. First, a pre-operatively evaluation of the AT was performed. Instead of a chemically destruction of transversal neo-vessels this treatment method aims to cut the vessels mechanically and at the same time partly separate the tendon from the adjacent fat tissue.

During the surgery the patients are in a prone position with both feet hanging relaxed outside the surgical table. After disinfection of the skin, with a solution of chlorhexidine, the skin is draped with a sterile paper-cover. The procedure is performed in infiltration anaesthesia, using Xylocain 1%, 10 ml in total. A sterile plastic draping is used to cover the US transducer and sterile gel is applied on the skin at the dorsal side of the tendon. US/CD are used per-operatively to guide the incision at the level corresponding to the tender area with structural changes and transversal ingrowth of vessels. A short longitudinal stab incision (<1 cm) through the skin is done at the medial side of the AT to minimize the risk of interference with the sural nerve. Through this medial incision a 1.2 × 50 mm gauge needle is inserted. During simultaneous greyscale US scanning the needle is directed to the area just outside the ventral part of the tendon, where the ingrowing vessels were cut off with the bevelled sharp edge of the needle (figure 4.6.1).

The CD function cannot be active during the movements of the needle, since it is highly sensitive to motion and creates a lot of colour-disturbances in the image. Thus, it is necessary to activate the CD regularly while keeping the needle immovable, to control if there is any transversal ingrowth of vessels left. The skin incision is closed using a single stitch, non-resorbable sutures. A light compression bandage should be applied for 24 hours. Then the patient was allowed walking but not training the affected tendon during the first 10-12 days following the treatment.

By using this technique, the tendon and the areas with structural tendon changes and the neovascularization are continuously shown in the operating field. This method allows the surgical procedure to precisely address the area of interest on the ventral surface of the tendon, and the trauma to the Kager’s triangle and the tendon is minimized.

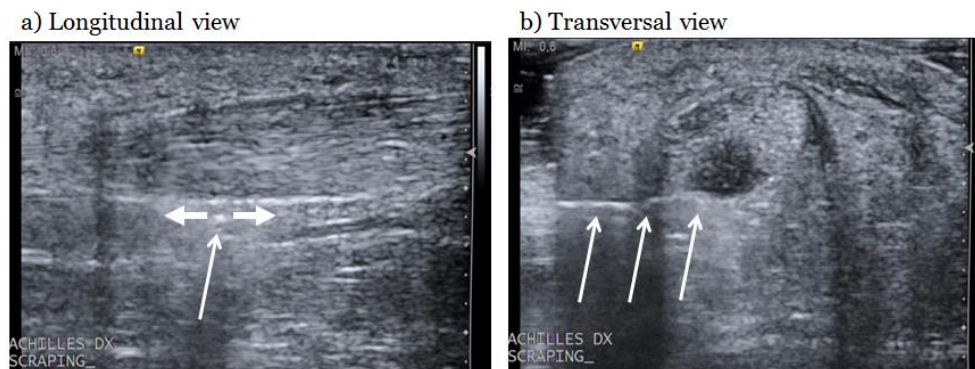


Figure 4.6.1. Longitudinal (a) and transversal view (b) of a midportion AT during treatment with US/CD-guided mini-invasive surgery, “scraping”. Vertical thin arrows pointing out the needle. Horizontal thicker arrows showing how the needle is moved, back and forth, “scraping” just outside the ventral surface layer of the tendon.

US/CD-guided arthroscopic surgery

The patients of group B, in study II had previously been treated with US/CD guided arthroscopy because of chronic painful *proximal patellar tendinosis* in a prospective randomized trial. Arthroscopy was performed under local anaesthesia. The patients were in a supine position with the knee extended and the quadriceps relaxed. The US transducer was draped with a sterile plastic cover and a sterile coupling gel was used on the skin as well as between the plastic draping and the transducer.

Just before starting the surgical procedure US and CD was used to visualise the proximal part of the PT, at the apical tip of the patella, and US images documenting the localisation

of transversal blood vessels at the dorsal side of the tendon were recorded. Initially, a standard arthroscopic evaluation of the whole knee joint was performed using standard anteromedial and anterolateral portals. Then the PT insertion into the patella was identified. For shaving, a 4.5 mm full radius blade shaver was used. The shaver blade and the arthroscope was inserted as perpendicular as possible relative to the proximal part of the tendon in order to optimise the ultrasound view. Simultaneous US imaging (longitudinal and transversal views) guided the procedure (figure 4.6.2).

Since it is not practical for the surgeon to use a triangulation technique that includes the US imaging, it is important that the sonographer is adaptable and provides adequate and stable projections to guide the shaving procedure. Careful shaving, aiming to destroy only the region with high blood flow and nerves adjacent to the tendinotic changes on the dorsal side of the tendon, was done (i.e. separating the central attachment of the Hoffa fat pad from the patellar tendon). The portals were closed with a tape, and a bandage was used for 24 hours. Then the patient was allowed walking but not training the affected tendon during the first 10-12 days following the treatment.

This technique offers less damage to the surrounding tissue compared to the open surgical techniques like removal of the tip of the patella, osteotomy (Pećina et al 2010) and tenotomy to remove macroscopically abnormal tissue. By adding real-time US imaging to the arthroscopic monitoring, the procedure of shaving was clearly visualised and the trauma to the Hoffa fat pad and the tendon could be minimized.

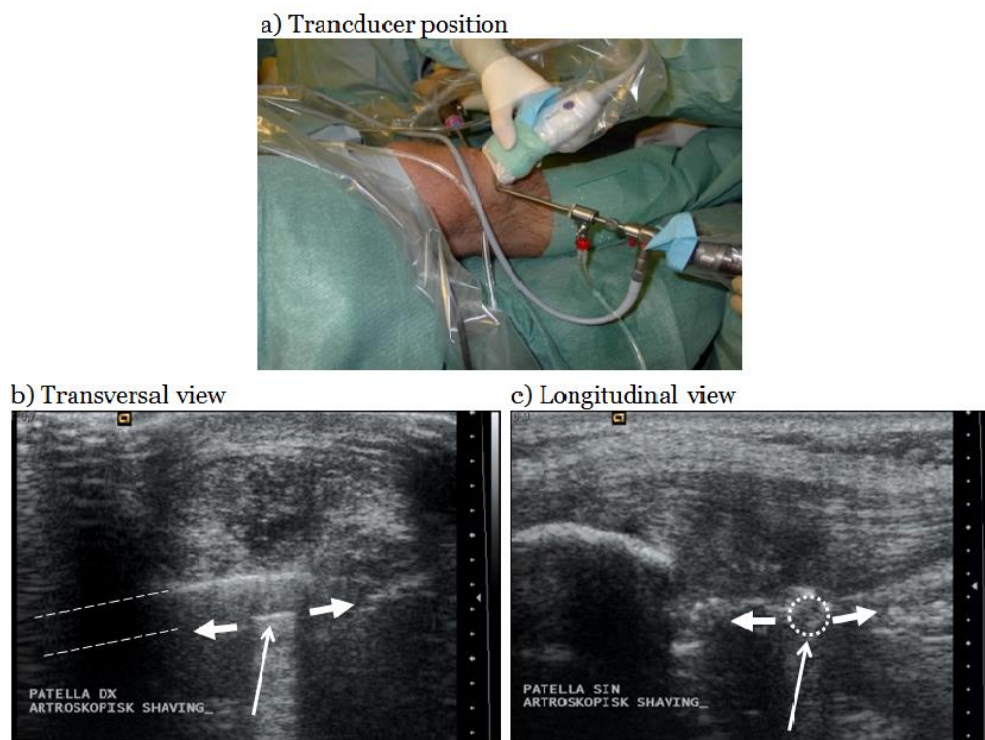


Figure 4.6.2. Transducer position (a) and arthroscopic portals are shown as well as transversal (b) and longitudinal (c) US views of a proximal PT during treatment with US/CD guided arthroscopic surgery. Vertical thin arrows pointing out the shaver and horizontal thicker arrows showing how the shaver is moved, laterally and back and forth, just outside the proximal dorsal surface layer of the tendon.

4.7 OUTCOME MEASURES

Visual Analogue Scale (VAS) for pain

VAS has shown to be a valid and reliable tool for evaluating acute pain (Bijur et al 2001, Williamson. et al. 2005, Boonstra et al 2008) and a pain reduction of 30-35%, scored on the scale, has been considered to be clinically relevant (Rowbotham 2001).

All patients in study II and IV scored the level of patellar tendon pain during their specific sport or recreational activity, and at rest, on a 100-mm long visual analogue scale (VAS), the worst experienced pain during the last two weeks was requested to be scored at all times (appendix 2).

VAS for satisfaction with treatment results

The VAS was also used for self-reported satisfaction with the results after treatment at every follow-up, in study II and IV (appendix 2). Complete satisfaction should be scored at 100 (%), on the scale, meaning painless return to the tendon loading activity that was desired at baseline, and no satisfaction at all should be scored at the zero-point (Ferreira-Valente et al 2011, Rowbotham 2001).

The Victorian institute for sport assessment (VISA) questionnaire

VISA-P; The Victorian Institute of Sport tendon study group (Melbourne, Australia) first developed an index of severity for patellar tendinopathy to facilitate jumper's knee research and subsequently, clinical management (Visentini et al 1998).

VISA-A; Later, a similar index was developed for Achilles tendinopathy (Robinson et al 2001).

Both questionnaires consist of eight questions to measure the degree of pain, function in daily living, and sporting activity. The results range from 0 to 100, where 100 represent the desirable score value. These questionnaires have been translated and culturally adapted for use in Sweden (Frohm et al 2004, Silbernagel et al 2005). (VISA-A in appendix 3)

The modified Öhberg score

In the present thesis the sonographic findings of AT and PT were evaluated using standardised criteria for tendon pathology. A 4-grade scale (0-3) was used when evaluating the amount of neovascularization inside the tendon, instead of the original 5-grade scale (0-4). In addition, we also used a 4-grade scale when evaluating the tendon structure. The Öhberg score was originally introduced in 2002 by Öhberg and co-workers investigating midportion Achilles tendinopathy (Öhberg et al 2002). Since then it has been used in a number of studies evaluating the amount of neovascularization in chronic painful tendons (Öhberg et al 2002, Öhberg et al 2003, Alfredson et al 2005a). The original Öhberg score does not provide any scale for evaluation of the extent of structural changes inside the tendon tissue. Furthermore, it does not pay any attention to the spreading or direction of the visible flow inside the tendon tissue. The modified Öhberg score used in this thesis pays attention to the spreading of the visible blood flow in a wider part of the tendon. It also pays attention to the direction of the flow, longitudinal or transversal. Inter- and intra-observer reliability for the use of this modified Öhberg score was evaluated in study I.

The criteria for the qualitative evaluations as well as illustrated examples follow below.

Tendon structure (echogenicity), figure 4.7.0 and 4.7.1

- 0 - normal structure (homogenous echogenicity)
- 1 - light structural changes (discrete hypo-echogenic areas)
- 2 - moderate structural changes (some well-defined hypo-echogenic areas)
- 3 - severe structural changes (extended hypo-echogenic areas)

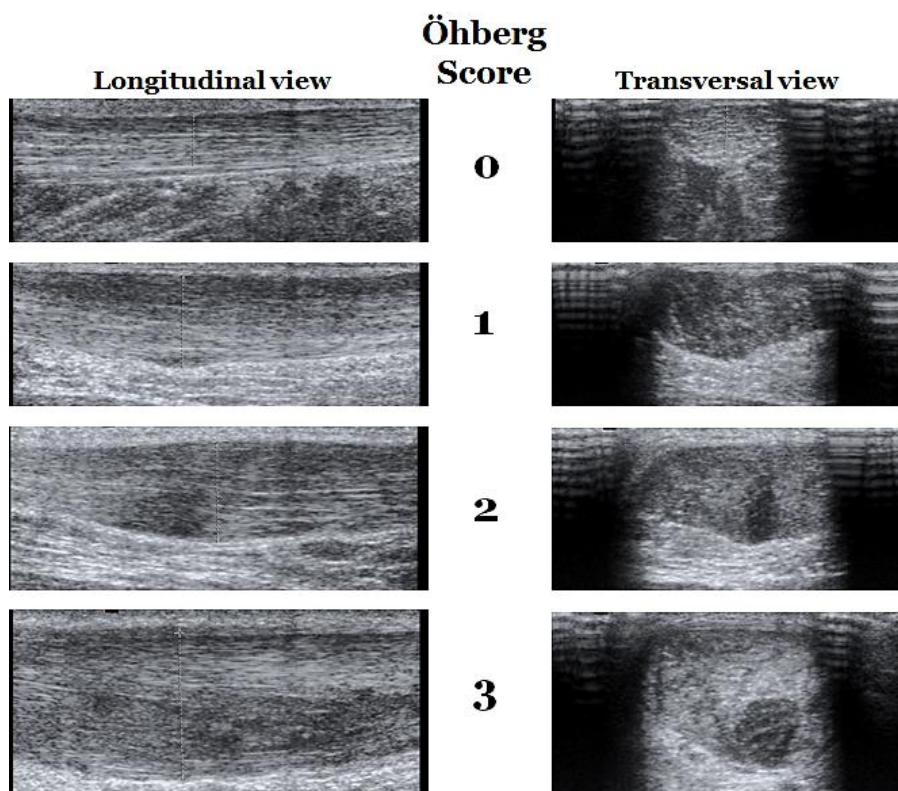


Figure 4.7.0. Illustration of Öhberg score for structural changes applied on midportion AT.

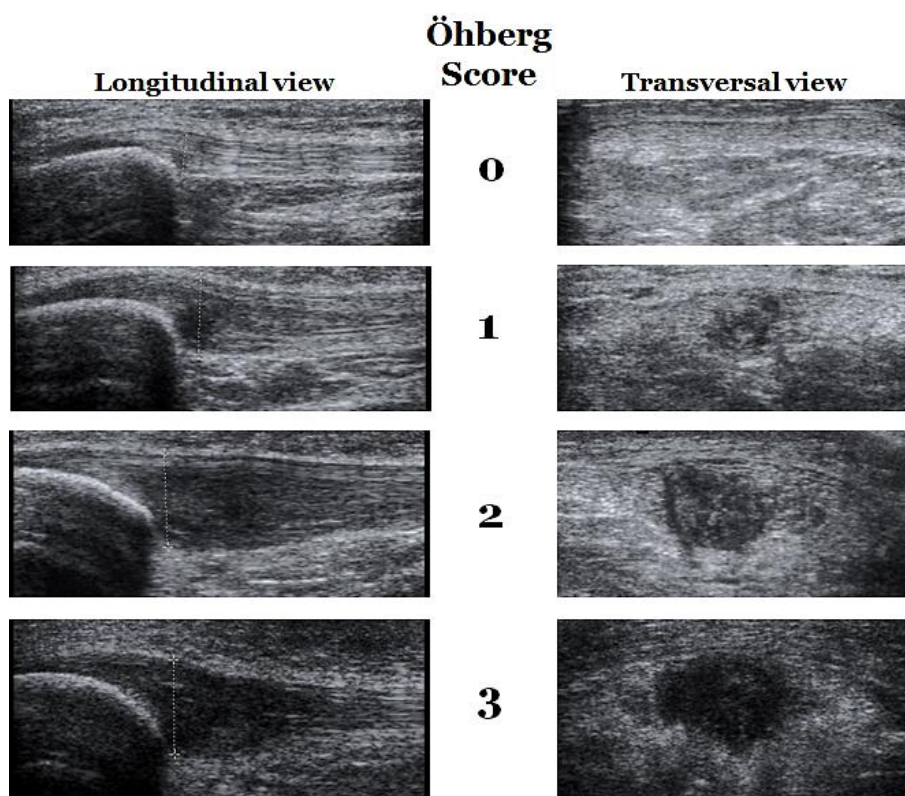


Figure 4.7.1. Illustration of Öhberg score for structural changes applied on proximal PT.

Neovascularization (visible increased blood flow), figure 4.7.3

0 - no visible vessels

1 - mild neovascularization (a few solitary transversal blood vessels in the deep part)

2 - moderate neovascularization (moderate quantity, mostly transversal blood vessels)

3 - severe neovascularization (several, mostly horizontal, vessels spread in the whole depth and in a wider part of the tendon)

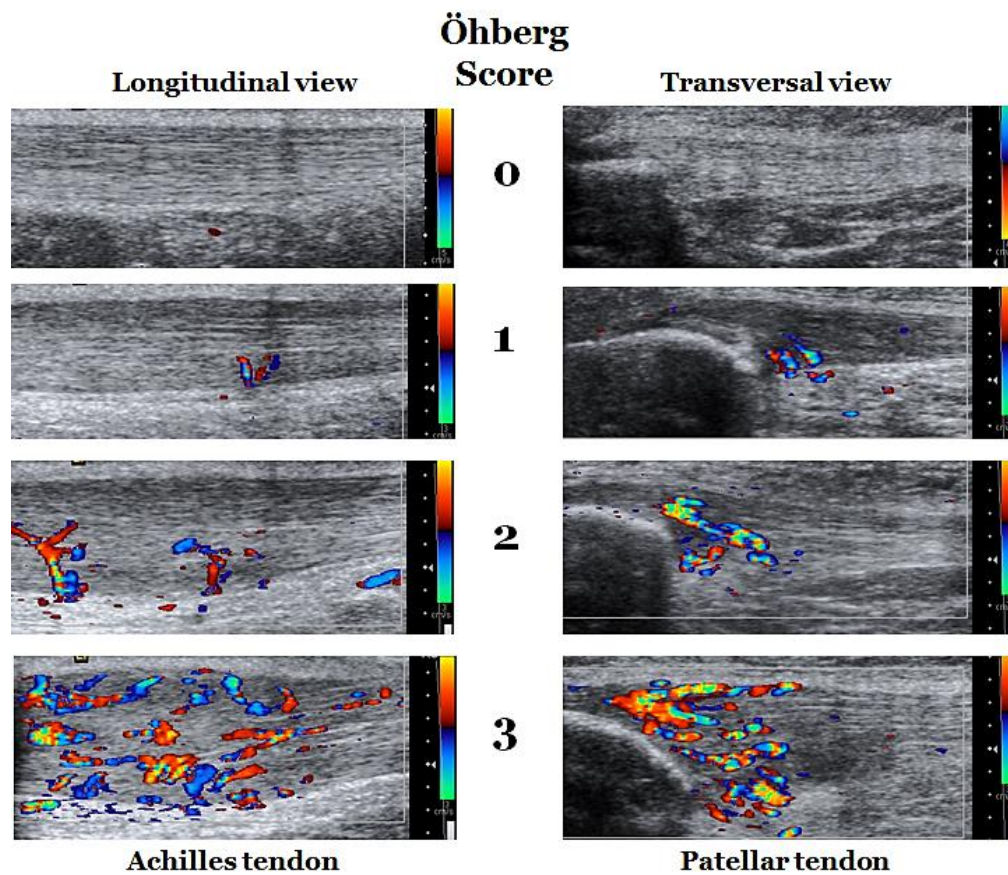


Figure 4.7.3. Illustration of Öhberg score for neovascularization applied on midportion AT and proximal PT.

4.8 STATISTICAL METHODS

All statistical analysis presented in the present thesis were performed using IBM SPSS package (version 21.0) Inc., Chicago, Illinois, USA (version 21.0) or IBM SPSS Statistics (version 22) Armonk, NY, USA. Furthermore, in study I, Excel Microsoft 2010 was used for calculation of coefficient of variance (CV).

Study I

Power analysis: At a desirable coefficient of variance (CV 2.5%) for repeated measures of the tendon thickness, and at a mean value of 5 mm (arithmetic average) the SD will be 0.125 and the confidence interval (CI) for a larger amount of observations will be 0.25 mm. According to our calculations, 24 repeated measures (48 observations) are required to determine the confidence interval with a precision of ± 0.05 at a power of 80%.

Statistical analysis: For sample description continuous data were presented as mean millimetre and standard deviation (SD), and ordinal data were presented as the median Öhberg score and inter quartile range (IQR). Evaluation of continuous variables was performed using *t*-test for analysis of systematic differences between symptomatic and asymptomatic tendons. For evaluation of the ordinal variables a Wilcoxon signed-rank test was used. Reliability regarding measures of distance was calculated as coefficient of variance (CV%), and Intra-class Correlation Coefficient (ICC) was used to evaluate the correlation between measurements performed by the different observers. Reliability regarding qualitative evaluation was calculated as Kappa coefficient (k). (Taylor 1990, Machin et al 2007)

Study II

The *power analysis* showed that 16 tendons in each group would be required to demonstrate a significant difference in mean AP-thickness between the two groups. Concerning Öhberg score for neovascularisation power analysis resulted in a sample size of 11 tendons in each group. Significance level was set to 0.05 and power to 80%.

Statistical analysis: Patient characteristics as well as descriptive frequencies were presented as mean and standard deviation (SD) for continuous variables and as median and inter quartile range (IQR) for ordinal variables. The statistical analysis for paired tests of both continuous and ordinal variables was calculated with the non-parametric Mann Whitney U-test. Differences between groups were calculated using a non-parametric test for independent samples, Wilcoxon signed-rank test. Spearman correlation was used for correlation analysis. A p-value of less than 0.05 was considered statistically significant.

Study III

Power analysis: We assumed a correct evaluation with MRI in at least 75% of the cases and with US in 80, 85 or 90% of the cases. The significance level was set to 0.05 and power to 80%. Given these conditions 315 shoulder cases were needed in the 75 vs 80% scenario, 100 in the 75 vs 85% scenario, and 35 in the 75 vs 90% scenario, in both groups.

Statistical analysis: The descriptive variables were presented as mean and standard deviation (SD). Spearman correlation and Kappa correlation coefficient were calculated for the ordinal variables. A p-value of less than 0.05 was considered statistically significant. Criterion validity (sensitivity, specificity and accuracy) were manually calculated.

Study IV

The power analysis was based on the results from a recent study, comparing sclerosing injections and surgical treatment (arthroscopic shaving) for patellar tendinopathy (25), which showed that 20 patients/tendons in each group were needed to give a power of 80% to find a difference of 50 mm in VAS between the groups, on a 5% significance level. We estimated a higher difference than normally accepted (a difference in VAS of 30 mm), to make sure that the groups were not too small. We hypothesized a similar difference in treatment results between the sclerosing injections and the mini-invasive surgery, regarding Achilles tendinosis. Since we are evaluating a new kind of mini-invasive treatment method we decided, to perform an interim analysis at “half-way” in a pilot study.

Statistical analysis: Patient characteristics are presented as mean and standard deviation (SD). Differences between groups were calculated using one-way ANOVA. The statistical analysis for paired tests of both continuous and ordinal variables was calculated with the nonparametric Friedman test for repeated measures. Independent tests between groups were calculated using nonparametric Kruskal Wallis test. A p value of 0.05 was considered statistically significant.

5 SUMMARY OF PAPERS

5.1 PAPER I

Evaluation of Achilles and patellar tendinopathy with greyscale ultrasound and colour Doppler: using a four-grade scale

In tendon research, using US, studies often refer to tendon thickness, structural abnormalities and neovascularization. However, the reliability concerning these measurements and evaluations is seldom reported (Cook et al 2001, Khan et al 2003, Genc et al 2005, Hirschmuller et al 2012, Giombini et al 2013). The aim of this study was to assess the intra- and inter-observer reliability for quantitative measures (thickness) and qualitative evaluations (structure and neovascularization) of symptomatic and asymptomatic AT and PT with US and CD using a modified Öhberg score. Furthermore, we also wanted to compare the reliability of evaluations and measurements performed by observers of different professions and experience-level. If the modified Öhberg score is found to be reliable, it could be used in defining the US/CD findings when investigating patients with tendinopathy. Furthermore, it could be a helpful tool when studying the tendon response after different treatments.

Material and methods

Twenty-eight consecutive patients, referred to Capio Artro Clinic in Stockholm, who suffered from chronic painful AT (8 males/7 females) or chronic painful PT (7 males/6 females), were asked to participate in this study. Both symptomatic and asymptomatic tendons were included. Three AT, showing signs of recent ruptures, were excluded. Three levels of reliability were evaluated:

- 1) a comparison between two sonographers performing a complete US/CD investigation of the same tendon independently; in this study referred to as complete inter-observer reliability test,
- 2) a defined inter-observer reliability test; a comparison between four observers, with different backgrounds and competences in evaluating US imaging, performing measurements and evaluations of the same US/CD images,
- 3) an intra-observer reliability tests; comparing the same four observers performing repeated measures and evaluations of the same US/CD images at two different occasions.

Tendon anteroposterior thickness was measured. Tendon structure and neovascularization were evaluated using the modified Öhberg score. US-images were evaluated twice by four independent observers. Sample descriptions are shown in table 5.1.0 below.

Table 5.1.0. Sample description

Variables	Achilles tendons (n=27)	Patellar tendons (n=26)
Males/Females, n	14/13	14/12
Right/Left, n	14/13	13/13
Age, mean (SD)	55 (11)	31 (10)
Symptomatic, n	16 (59%)	13 (50%)
Asymptomatic, n	11 (41%)	13 (50%)

Outcomes

Mean AP thickness for AT and PT was 8.4 mm (± 2.0) and 5.5 mm (± 1.7), respectively. The reliability for measures of distance was generally high (ICC = 0.983–0.998).

A moderate-strong correlation was found between observers concerning evaluation of neovascularization in both AT ($r = 0.77$ – 0.92) and PT ($r = 0.88$ – 0.99). Correlation was found to be poor-moderate concerning evaluation of structural changes in AT ($r = 0.38$ – 0.70) and moderate-strong in PT ($r = 0.72$ – 0.84).

Intra-observer reliability was moderate-strong for evaluations of both tendon structure ($k = 0.54$ – 0.87) and neovascularization ($k = 0.64$ – 0.86) including both AT and PT.

Conclusions

With a strict method for how to measure tendon thickness and set criteria for evaluating structural changes and amount and distribution of neovascularization, US/CD is a reliable method for evaluating AT and PT. The modified, 4-graded, Öhberg score showed qualifications to be a useful and reliable instrument when evaluating status and progress of AT and PT disorders. However, when comparing sonographic findings over time we suggest that evaluations are performed by the same sonographer/observer, based on higher intra-observer reliability in general.

5.2 PAPER II

Sclerosing injections and ultrasound guided arthroscopic shaving for patellar tendinopathy: good clinical results and decreased tendon thickness after surgery - a medium-term follow-up study

Treatment of patellar tendinopathy/jumper's knee with US/CD guided sclerosing injections or US/CD guided arthroscopic shaving has shown good clinical short-term results. Former studies indicate that the tendon thickness and structure stays unaffected after successful treatment (Alfredson et al 2009, Hoksrud et al 2008). The aim of this study was to evaluate the sonographic findings and clinical outcome 3–5 years after treatment of jumper's knee with US/CD guided sclerosing injections or US/CD guided arthroscopic shaving.

Material and methods

The patients approached in this study were 45 former participants in a prospective randomised trial (Willberg et al 2011) – for evaluating treatment with US/CD-guided sclerosing injections and US/CD-guided arthroscopic shaving, respectively - and an additional 9 patients from a previous pilot study evaluating the US/CD-guided arthroscopic shaving method, for patellar tendinopathy/jumper's knee (Willberg et al 2007). A total of 43 patients (41 males/2 females) with 57 treated tendons chose to participate in this follow-up study.

All patients included in this study were evaluated with US and CD. They also scored their level of PT pain during their specific sport or recreational activity, and at rest, on a 100-mm VAS-scale. Self-reported satisfaction with the result of treatment was also scored (0-100). All scores were compared with the corresponding scores before treatment and at the short-term follow-up (mean 12 months). Basic data are given in table 5.2.o.

Table 5.2.o. Patient characteristics and time to follow-up and endpoint. Group A, patients treated with sclerosing injections and group B, patients treated with arthroscopic shaving. Significance level for differences between groups was calculated with independent *t*-test and a *p*-value less than 0.05 was considered significant.

Variables	Group A (n = 19)		Group B (n = 25)		p-value
	Mean	(SD)	Mean	(SD)	
Males/Females (n)	18/1		23/2		ns
Age (years)	27	(±10)	27	(±8)	ns
Height (cm)	182	(±6)	182	(±5)	ns
Weight (kg)	78	(±8)	80	(±8)	ns
BMI	23.3	(±1.2)	24.4	(±2.6)	.048
Duration of symptoms (months)	21	(±12)	23	(±17)	ns
Time to follow-up (months)	15	(±7)	13	(±5)	ns
Time to endpoint (months)	44	(±8)	48	(±8)	ns

Outcomes

In the group treated with US/CD-guided arthroscopic shaving the mean AP thickness of the proximal patellar tendon had decreased significantly from baseline to endpoint. In the US/CD-guided sclerosing injection group there was initially a significant increase in proximal PT thickness but at endpoint, the tendon thickness was similar to before treatment. The tendon structure had improved significantly, and there was significantly less neovascularisation at the short term follow-up compared to baseline, in both treatment groups.

There was no further significant improvement at endpoint for the group treated with US/CD guided arthroscopic shaving.

A sonographically more normal tendon structure was seen earlier in the group treated with US/CD-guided arthroscopic shaving. At final endpoint, there was a significant decrease in VAS for pain during activity in both groups and no significant difference in VAS between the groups. The results are shown in figure 5.2.1.

Furthermore, 74 % of the patients in the sclerosing injection group and 80% of the patients in the arthroscopic shaving group scored >80% in VAS for satisfaction with their treatment result at endpoint.

A significant correlation between low local blood flow and high patient satisfaction was found (follow-up -0.45 $p < 0.01$; endpoint -0.56 $p < 0.001$) both at follow-up and at endpoint. At short-term follow-up a correlation was found between increased tendon thickness and high VAS for pain at rest (0.66 $p < 0.01$) in the arthroscopic shaving group. When including the whole material (US/CD findings and VAS for pain during activity), regardless of time, a significant correlation was found between the magnitude of increased visible blood flow (neovascularization) and VAS for pain during activity (0.63 $p < 0.0001$) as well as between the level of structural changes (0-3) and VAS for pain during activity (0.52 $p < 0.0001$).

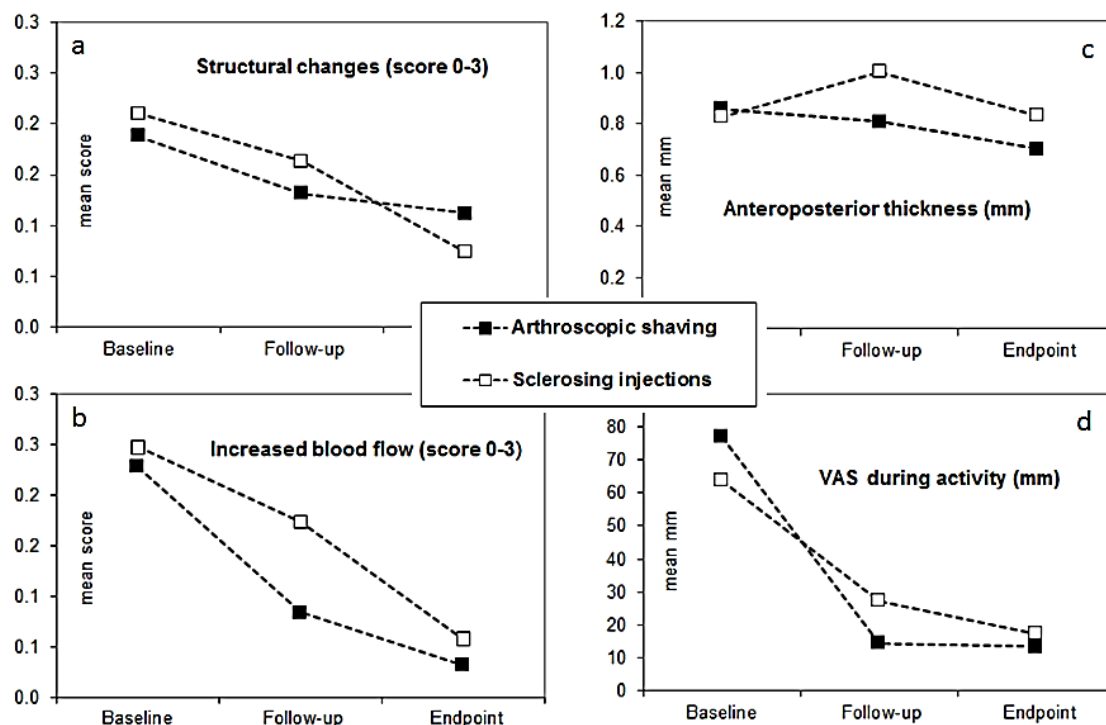


Figure 5.2.1. Comparison between the groups regarding, structural changes, increased blood flow, AP-thickness and VAS during activity. Graphs with un-filled dots represent group A (sclerosing injections) and graphs with filled dots represent group B (arthroscopic shaving) at baseline, follow-up (~15 months) and endpoint (~46 months).

Conclusion

In conclusion, in this 3-5-year follow-up study, there was a remodelling and a sonographically more normal patellar tendon after successful treatment with US/CD-guided arthroscopic shaving. After treatment with sclerosing injections and arthroscopic shaving of jumper's knee, there was a correlation between low score for pain during activity, high patient satisfaction and low local blood flow. Both treatment methods rendered good and equal clinical results at 46 months. US/CD-guided arthroscopic shaving showed a significantly faster return to sport activity, and patient satisfaction could be noticed at an earlier point.

5.3 PAPER III

Office-based ultrasound imaging of rotator cuff tears – the accuracy when performed by a biomedical technician specialized in musculoskeletal ultrasound.

Despite the fact that US, in several studies, has shown to be an accurate imaging modality (Crass et al 1984, Brenneke et al 1992, van Holsbeeck et al 1995, Teefey et al 2000, de Jesus et al 2009) MRI is still the customary method for examination of rotator cuff disorders (Seeger et al 1998). Studies evaluating the validity of ultrasound (US) for detection of rotator cuff tears, performed by orthopaedic surgeons instead of radiologists, have shown sufficient accuracy and reliability (Iannotti et al 2005, Al-Shawi et al 2008, Jeyam et al 2008), but still this is not very commonly occurring. The primary aim of this study was to investigate whether a biomedical technician (BT), with long experience in performing US, could interpret pathological findings with a similar degree of accuracy as trained musculoskeletal radiologists. For this purpose arthroscopic surgery was used as reference method. A secondary aim was to evaluate the possible differences in the diagnostic value of US imaging, close to the clinical examination, compared to the regular concept of MRI performed several months prior to the clinical examination and decision of treatment.

Material and methods

One hundred and seventy two (n=172) consecutive patients, referred to Caphio Arthro Clinic in Stockholm, with symptoms indicating shoulder impingement or rotator cuff injury, underwent US examination in conjunction with a clinical examination - performed by a physiotherapist together with an orthopaedic surgeon. Eighty-two patients underwent MRI and US of the shoulder prior to arthroscopic surgery. Basic data concerning those 82 patients are shown in table 5.3.0. US imaging was performed by a BT, in conjunction to the clinical examination.

The findings from US, MRI and arthroscopy were compared. An identical pre-election protocol was used to document the findings from all three diagnostic modalities (appendix 5).

Table 5.3.0. Basic patient data

Variables	Males	Females	All
	N=55	N=27	N=82
	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	54 (±9)	54 (±10)	54 (±9)
Height (cm)	180 (±8)	165 (±6)	175 (±10)
Weight (kg)	87 (±12)	65 (±10)	80 (±16)
BMI	26.9 (±3.5)	23.8 (±3.7)	25.9 (±3.8)
	N (%)	N (%)	N (%)
Right shoulder	35 (64)	18 (67)	53 (65)
Left shoulder	20 (36)	9 (33)	29 (35)

Outcomes

Sixty-two full-thickness tears (FTT) including complete tears (CT), and 29 partial thickness tears (PTT) were confirmed by surgery in the 82 shoulders that were assessed with all three diagnostic modalities. Out of these injuries 51 (56%) were found in the supraspinatus tendon (38 FTT/13 PTT), 19 (21%) in the infraspinatus tendon (15 FTT/4 PTT), and 21 (23%) in the subscapularis tendon (9 FTT/12 PTT). US could detect 87% of all injuries and correctly detect 85% of the full-thickness tears and 55% of the partial thickness tears. Correlations between US and surgery and between MRI and surgery are shown in table 5.3.1. The results from US and MRI evaluations are shown in figure 5.3.2 and 5.3.3.

Regarding full-thickness tears, including all tendons of the cuff, US showed a sensitivity of 85%, a specificity of 91% and accuracy of 90%. Based on evaluations of the supraspinatus tendon alone US showed a sensitivity of 100%, a specificity of 89% and accuracy of 94%. The corresponding results from MRI were 87%, 86% and 86%. The mean time-frame, described in weeks, between US and surgery as well as between MRI and surgery was 8 (± 9) and 36 (± 41), respectively.

Table 5.3.1. Correlation between US and Surgery, MRI and Surgery, and between US and MRI, expressed as Spearman correlation and Kappa coefficient.

		Arthroscopy n=82	
		Spearman (SE)	Kappa (SE)
Supraspinatus	US	.890 (.019)	.563 (.065)
	MRI	.771 (.058)	.513 (.068)
	p-value	.001	
Infraspinatus	US	.509 (.110)	.406 (.097)
	MRI	.436 (.126)	.186 (.071)
	p-value	.555	
Subscapularis	US	.504 (.105)	.312 (.088)
	MRI	.592 (.102)	.422 (.102)
	p-value	.430	

Note; Mean time between US and Surgery: 8 weeks; between MRI and Surgery: 36 weeks

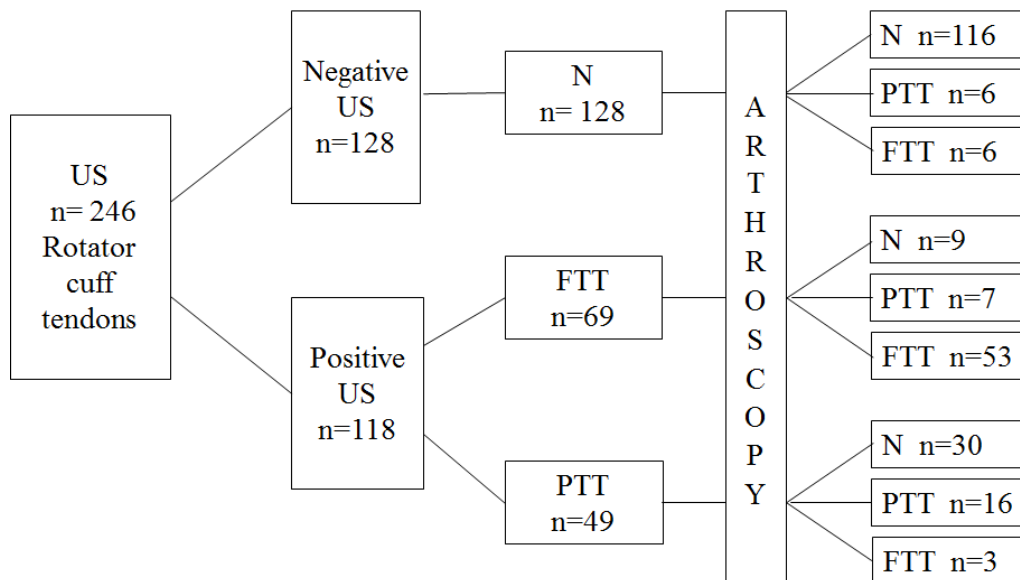


Figure 5.3.2. Results of the US evaluations (82 patients/246 tendons) regarding the rotator cuff tendons, compared with true findings at arthroscopy. FTT = Full thickness tear including complete tear; PTT = Partial thickness tear; N = No tear (normal and tendinosis).

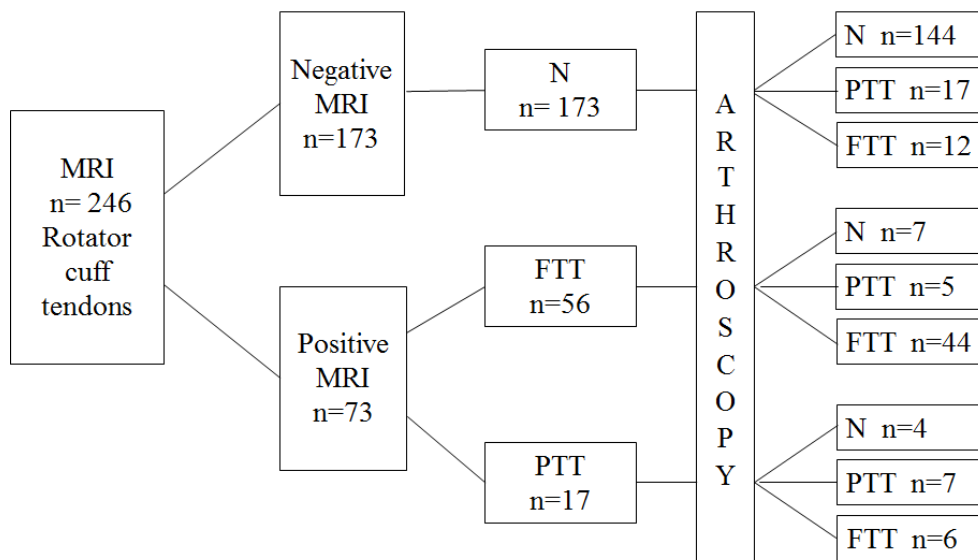


Figure 5.3.3. Results of the MRI evaluations (82 patients/246 tendons) regarding the rotator cuff tendons, compared with true findings at arthroscopy. FTT = Full thickness tear including complete tear; PTT = Partial thickness tear; N = No tear (normal and tendinosis).

Conclusion

We conclude that office-based US imaging of the shoulder, performed by a trained BT, showed a sufficient accuracy in detecting significant rotator cuff tears. The diagnostic value of the US imaging performed in connection to the clinical examination was higher than the MRI results performed considerably earlier than the clinical examination, in terms of identifying rotator cuff tears.

5.4 PAPER IV

Treatment of midportion Achilles tendinosis: Ultrasound-guided mini-invasive surgery, sclerosing injections or eccentric training - a randomized controlled pilot study.

Chronic painful midportion Achilles tendinopathy is a common diagnosis at an out-patient orthopaedic clinic. This disabling problem seems to afflict people regardless of activity level, but is most commonly seen in physically active patients, ranging from recreational to competitive level (Kvist et al 1994, de Jonge et al 2011). A great number of attempts to treat this persistent disorder have been described and performed by physicians, physiotherapists and chiropractors, not always with complete satisfaction and with an annoying delay in treatment results. In this study we are presenting the short term interim results (6 months) of a new US/CD-guided mini-invasive surgical treatment for chronic painful midportion Achilles tendinopathy in comparison with the results of the standard protocol ECC and sclerosing (Polidocanol) injections.

Material and methods

Thirty-four patients (42 tendons) with US and CD verified midportion Achilles tendinosis were randomly assigned, according to a block-randomization scheme, to one of three treatment methods. All patients were involved in sport or recreational activities and have had pain for more than 3 months. Using VAS, pain during activity and at rest was registered before and after treatment, as well as satisfaction with the result of the treatment. The VISA-A questionnaire was used to evaluate the progress in functionality. A flowchart describing the patient's participation through the study is shown in figure 5.4.0. Basic data are reported in table 5.4.1.

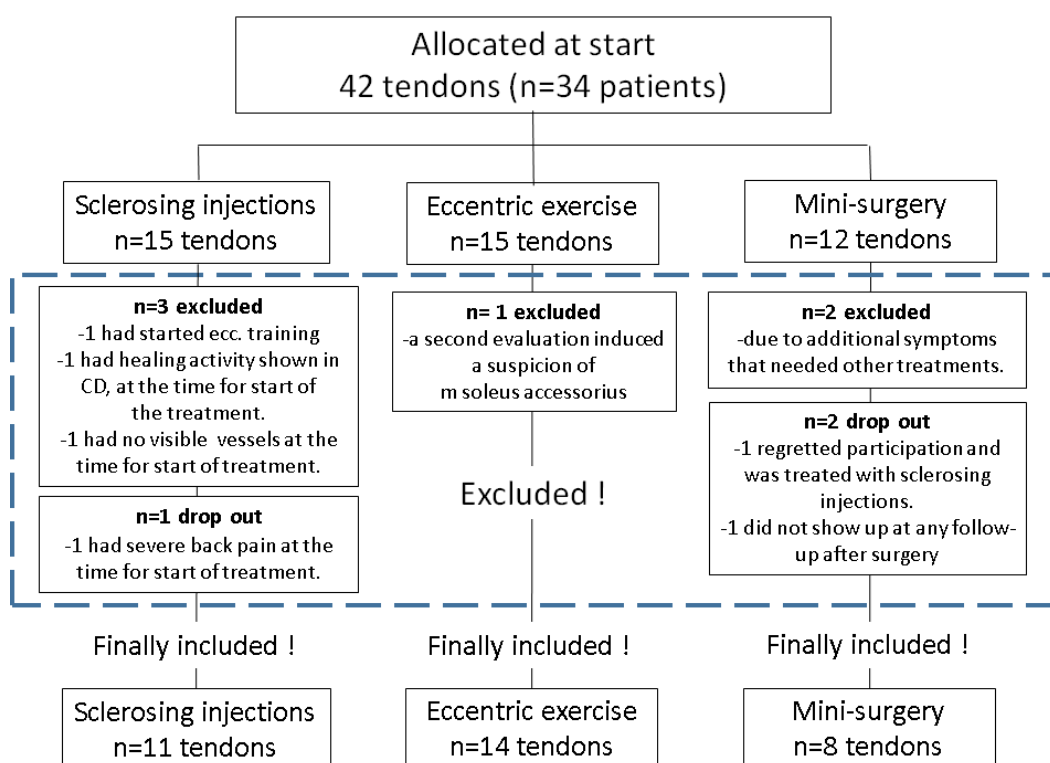


Figure 5.4.0. Flowchart describing the patient's participation in the different treatment groups.

Table 5.4.1. Basic data; Group A - tendons treated with ECC, Group B – tendons treated with US/CD-guided sclerosing injections, Group C tendons treated with US/CD-guided mini-invasive surgery. Differences between groups were calculated using one-way ANOVA (* = p-value <0.05).

	Group A 11pt (14tend)	Group B 9pt (11tend)	Group C 8pt (8tend)	
Variables	Mean (SD)	Mean (SD)	Mean (SD)	p-value
Gender (males/females)	8/3	3/6	2/6	
Age, years	50 (±10)	49 (±10)	48 (±7)	.893
Height, cm	178 (±7)	174 (±10)	167 (±10)	.027
Weight, kg	80 (±16)	78 (±7)	82 (±12)	.875
BMI	24.8 (±3.5)	26.1 (±2.8)	29.2 (±4.5)	.031
Duration of symptoms, months	12 (±6)	30 (±31)	23 (±22)	.117

Note: pt = patients, tend = tendons.

Outcomes

The primary outcome was the 6 months' clinical effect of treatment evaluated with VAS (0–100) for pain during activity and for patient satisfaction regarding the results of the treatment, and with VISA-A questionnaire for the progress in tendon functionality. Furthermore, US measurements regarding tendon thickness were evaluated. Six months after the start of the treatment all clinical variables were improved in all three treatment groups. However, the decrease in VAS at rest in the surgical group, and in VAS during activity in the sclerosing injection group was not significant at this point. The group treated with ECC scored the highest on VISA-A (82 ± 13), and in VAS for satisfaction with treatment (84 ± 28), followed by the group treated with mini-invasive surgery ($67 \pm 22/66 \pm 30$), and the group treated with sclerosing injections ($57 \pm 25/51 \pm 37$). The results are shown in figure 5.4.2. and table 5.4.3.

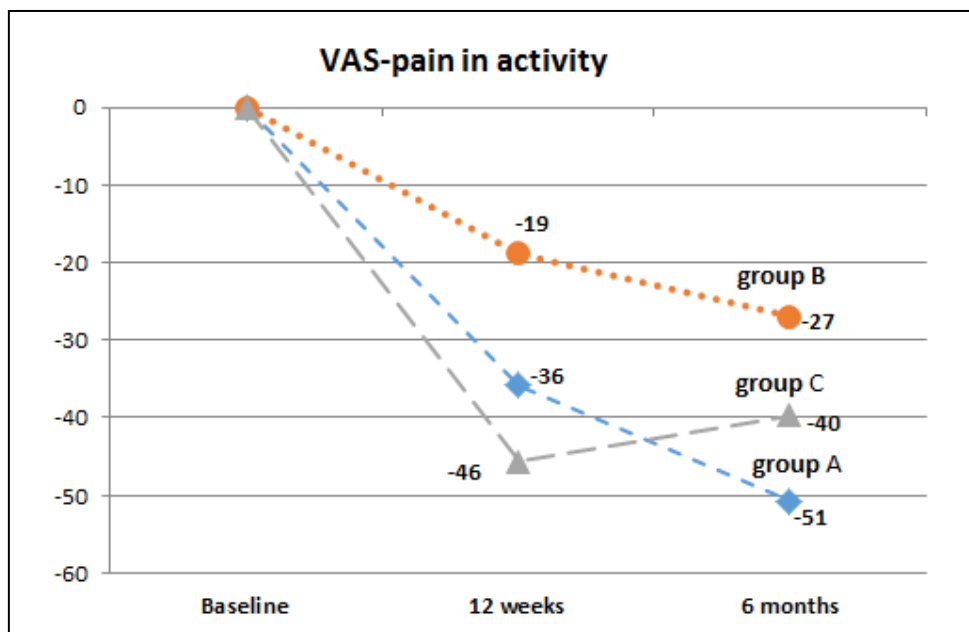


Figure 5.4.2. Decrease in VAS for pain in activity. Group A= ECC, group B= US/CD-guided sclerosing injections and group C= US/CD-guided mini-invasive surgery.

Table 5.4.3. Clinical outcome and AT thickness at baseline, at 12 weeks follow-up and at 6 months follow-up. The statistical analysis for paired tests of continuous and ordinal variables was calculated with the nonparametric Friedman test for repeated measures (p-value <0.05). A represents patients treated with ECC, B patients treated with US/CD-injections and C patients treated with US/CD-surgery.

Variables		After the start of the treatment			p-value
		Baseline	12 weeks	6 months	
		Mean (SD)	Mean (SD)	Mean (SD)	
VAS-pain at rest (0-100)	A (n=14)	26 (±29)	8 (±11)	10 (±20)	.032
	B (n=11)	60 (±31)	37 (±36)	28 (±31)	.257
	C (n=8)	45 (±26)	9 (±10)	17 (±32)	.118
VAS-pain during activity (0-100)	A (n=14)	66 (±22)	30 (±28)	15 (±22)	.000
	B (n=11)	81 (±22)	62 (±33)	54 (±32)	.273
	C (n=8)	76 (±14)	30 (±22)	36 (±28)	.010
VISA-A (score 0-100)	A (n=14)	50 (±18)	78 (±15)	82 (±13)	.000
	B (n=11)	38 (±14)	48 (±26)	57 (±25)	.103
	C (n=8)	40 (±12)	66 (±17)	67 (±22)	.030
Tendon thickness (mm)	A (n=14)	9.7 (±2.2)	9.8 (±2.4)	9.2 (±2.2)	.353
	B (n=11)	9.3 (±1.3)	10.4 (±1.3)	10.2 (±1.6)	.003
	C (n=8)	8.2 (±1.5)	8.9 (±2.0)	9.0 (±2.9)	.495

Note; n= numbers of tendons

6 DISCUSSION

6.1 GENERAL DISCUSSION

Since my first contact with diagnostic US, in the middle of the 1980s, I have experienced a lot of new technical innovations and along with those also many new insights regarding the interpretation of US findings. However, my point of view is that no matter how well US - or any other diagnostic imaging techniques for that matter - can present a tissue and/or a dynamic event, it can never replace or downsize the advantage of a well performed clinical examination. Diagnostic imaging should, in my opinion, primarily be used to verify or exclude abnormalities and to present additional information valuable for the choice of the most appropriate treatment method.

Another exciting field of application, with great potential, is the use of US for guidance of different invasive treatments. US has since many years been used by radiologists and cardiologists as guidance when performing different invasive interventions in their field. This has increased the interest for the technique at different care units including orthopaedic out-patient clinics, particularly in sports orthopaedics/traumatology. From the view of such an out-patient clinic the whole idea and design of this thesis has been developed. The general purpose was to highlight and evaluate the use and accuracy of US - for *diagnostics*, *treatment guidance*, and *evaluation of treatment results* regarding some of the most common musculoskeletal overuse injuries and pain disorders, at an orthopaedic sports medicine clinic.

There is no doubt about the benefits of having access to the US imaging technique at an out-patient orthopaedic sports medicine clinic. At Capio Artro Clinic we have experienced a great advantage with a close collaboration between a specialized sonographer - with knowledge in US physics, including limitations and pitfalls of the method - and the clinician - e.g. an orthopaedic surgeon and/or physiotherapist - with knowledge in practical anatomy and injury mechanisms. Furthermore, except from the convenience for the patients to have their diagnostic imaging in close connection to the clinical examination, some of the treatments described in this thesis would probably not have been realized at all if it wasn't for this clinical setting and "team-work". Those US/CD-guided treatment methods require supervision and commitment by an experienced orthopaedic surgeon, specialized in sports medicine and arthroscopy. It would have been difficult to achieve continuity in this kind of health care activity if it was located and performed in collaboration with a radiological department.

6.2 EVALUATION OF US FINDINGS IN TENDINOPATHY

Tendons are the most common problem area examined with US at Capio Artro Clinic, and painful tendinopathy is the most frequent area of disorders with great need for US/CD diagnostics. US has become very important when dealing with tendon injuries/tendinopathy. The most common diagnosis we find is the painful tendinosis. Personally I think it is necessary to ensure the correct underlying diagnosis, since the treatment really differs when comparing tendinosis and a partial rupture or for example bursitis in AT insertional problems.

When addressing tendinosis, the patients describe a successive onset of the pain that progresses to a sharp pain during tendon loading. The tendon is very tender at palpation and there is a swelling of the area. With US we can see that compared to the normal, healthy tendon, it has become thicker, there are some hypoechoic areas and most often we can identify some visible high blood flow crosswise to the tendon fibres in the deep part of the tendon (figure 6.2.0). However, it takes US with CD or PD to visualize this!

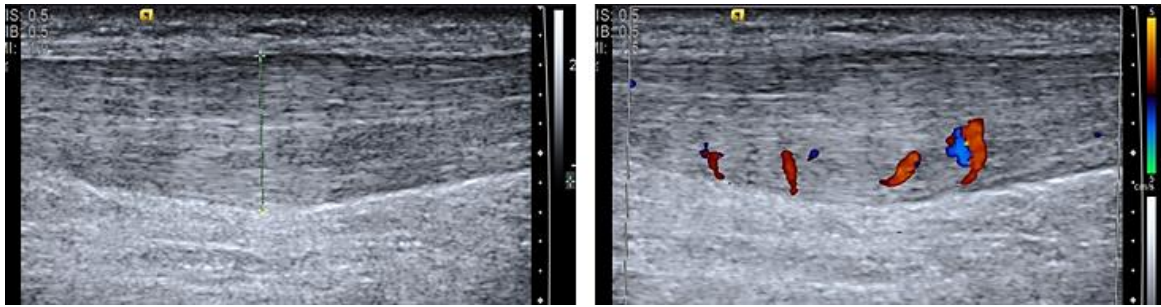


Figure 6.2.0. Classical US images of a midportion Achilles tendinosis.

There is another situation that clinically might appear almost the same except for that the sharp pain during loading often has faded away. By using the US/CD we can easily see that we are dealing with a tendon with an increased thickness in a wider part. Sometimes there is an improved structure and, above all, an increased amount of visible blood vessels with a completely different distribution – lengthways (longitudinal) instead of crossways (transversal) and in the whole depth of the tendon (figure 6.2.1). This appearance is what we consider being a healing process, also described by Alfredson and Öhberg in a “letter to editor” in 2006 (Alfredson et al 2006).

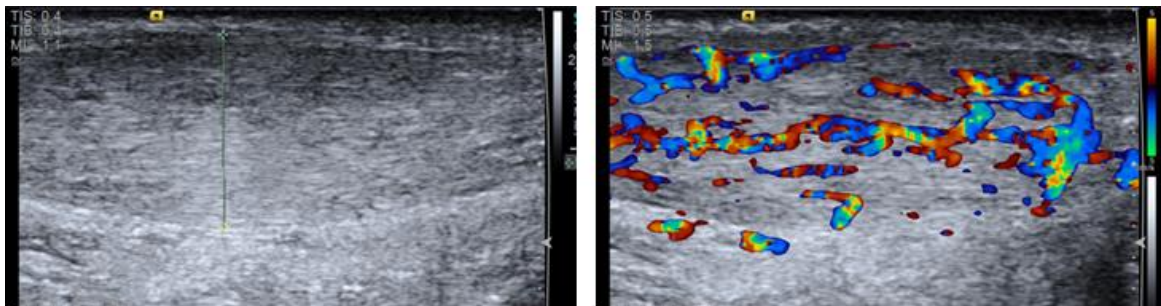


Figure 6.2.1. Midportion Achilles tendinosis during a healing process (?).

To be able to describe the differences in appearance of tendinotic tendons we need some reliable, “easy to use”, and reproducible tool. This is important if we want to compare results from different treatments, studies and also for understanding the different phases of this specific disorder.

On account of our own experience, we believe that when it comes to evaluating the neovascularization inside the tendon tissue, it is not just the amount of visible high blood flow that should be of interest, but also the direction and spreading of the vessels inside the tendon tissue. This could facilitate the comparison of results between different studies concerning tendinopathy. Increased blood flow, visible with CD or PD, is rarely seen in tendons that are considered as healthy. However, in chronic painful tendinopathy there is often more or less ingrowth of blood vessels from the adjacent fat tissue, perpendicular to the tendon fibres, in to the area of hypoechoic changes. Furthermore, we have noticed that AT and PT with small partial ruptures often show a “firework” of longitudinal vessels with high blood flow, seen with CD/PD, spread in an extended part and in the whole depth of the tendon demonstrating a healing process (inflammation).

The same image is often seen in chronic painful tendons in a stage where the patients express an amelioration of symptoms; loss of sharp disabling pain during tendon loading and instead an increased stiffness and soreness at rest after exercise. These patients describe an increased and somewhat painful stiffness at take-off, e.g. first steps in the morning or after a short brake during the day, with relief of symptoms when the tendon gets warmed up. These circumstances make it doubtful that there should be a straight relationship or linear correlation between the amount of visible blood flow and the extent of pain evaluated with VAS.

Gender and US findings in tendinopathy

It is known that the incidence of musculoskeletal injuries during physical activity is higher in women than in men. The tendon collagen synthesis rate has shown to be lower in women both in the resting state and after exercise (Miller et al 2007). Furthermore, a previous study indicate that tendons in women have a lower rate of new connective tissue formation, respond less to mechanical loading, and have a lower mechanical strength, making the tissue more susceptible to injury (Magnusson et al 2007).

The tendon capillary blood flow in symptomatic Achilles tendinopathy has shown to be similar in men and women but the tendon and paratenon microcirculation seems to be better in women (Knobloch et al 2008).

In patient with asymptomatic AT pathology a difference in fat distribution was found between males and females. Men had a more central distribution of fat, while women with asymptomatic tendon pathology had a more peripheral distribution of fat in comparison to match with normal tendons (Gaida et al 2010). The authors of this study interpreted that differences in adipose tissue distribution precede tendon pain.

The incidence rate of midportion Achilles tendinopathy has been found to peak in the age between 21-40 years in women and between 41-60 years in men (de Jonge et al 2011).

No studies reporting differences in US findings, such as tendon structure or colour flow distribution, between males and females with tendinopathy, could be found. However, in a study by Koivunen-Niemelä and co-workers the AT were found to be slightly thicker in men than in women in the age group 30-80 years (Koivunen-Niemelä et al 1995).

6.3 OUTCOME INTERPRETATIONS

In **study I** of this thesis, inter- and intra-observer reliability have been addressed - concerning measures of tendon thickness and evaluations of structural changes and neovascularization, with the use of a *modified Öhberg score*.

The score is assumed to be helpful instrument when studying the tendon response after different treatments. In these cases, the interest is not only to differentiate between normal and abnormal, but also to define the tendon changes at inclusion, and detect small sonographic changes and trends over time. With a reliable score able to define and describe the direction and spreading of the increased blood flow, in both depth and length of the tendon, it might lead to a better objective understanding of the pathology and the healing process of tendon pathology.

We found that the AP-thickness in AT and PT was relatively easy to determine and reproduce. Differences in *intra*-observer reliability between the observers, using the modified Öhberg score, were negligible when looking at evaluation of neovascularization but somewhat obvious when looking at evaluations of the tendon structure. The two most US experienced observers were slightly better in reproducing their results but it still seemed to be more difficult to reproduce structural abnormalities than neovascularization according to the Öhberg score.

There is a need to compare US/CD findings between different research projects concerning the chronic painful tendon. This study suggests that the *modified Öhberg score* can be used for assessment of the tendon structure and the amount of neovascularization both in research and for clinical matters. It would also be of value to describe what level of US and clinical experience the operator, performing the US/CD examinations in studies, possesses.

If keeping a strict method when evaluating US/CD-findings, the dependence of operator experience and technical skills does not seem to be that critical when it comes to following the same tendon over time, based on higher intra-observer reliability in general. For diagnostics it is, however, probably wise to engage experienced operators well educated in US technology and with at least some years of clinical experience of tendon pathology.

In some knees with clinically diagnosed patellar tendinosis/jumper's knee, no sonographic pathology, neither structural changes nor neovascularization were found. This implicates that patellar tendinosis/jumper's knee should not be considered solely as a clinical diagnosis as suggested by Blazina (1973) and Ferretti (1986). However, as suggested by Cook et al (1998 and 2001) the imaging finding of patellar tendinosis with hypo-echoic regions alone is

not clinically relevant since asymptomatic patellar tendinosis also exists. Hence, management of patellar tendinosis/jumper's knee shouldn't be solely based on neither US appearance nor clinical assessment. We believe that US/CD in combination with clinical evaluation and patient history of pain is required to be able to specify the diagnosis of patellar tendinosis/jumper's knee, consisting of chronic impairing pain and the specific tendinotic US/CD findings in the tendon.

In **study II** we found a significant decrease in proximal PT thickness after the US/CD guided arthroscopic shaving procedure. To the best of our knowledge this is the first time this has been reported after treatment of patellar tendinopathy. The findings clearly show the potential in the soft tissue dorsal to the proximal PT, where interference with careful and precise US/CD guided surgical shaving, but not with US/CD guided sclerosing injections, seems to have an impact on tendon thickness.

The US/CD guided arthroscopic procedure rendered a quicker painless return to full activity and sports as well as a higher number of satisfied patients at the short-term follow-up than sclerosing injections. This might be due to that the US/CD guided shaving procedure is more radical (the region with vessels and nerves is more traumatized) than the US/CD guided sclerosing injection treatment. Interestingly enough, the correlation analysis showed that the arthroscopic shaving procedure was associated with a faster decrease of neovascularization.

When reading the literature about how to treat tendinopathy at different locations, we found contradictory interpretations about whether the tendon tissue, of a successfully treated tendinosis, normalizes or not (Alfredson et al 2009, Lind et al 2006). In figure 6.3.0 you find an example of a typical case included in study II, concerning patellar tendinosis, treated with sclerosing injections, clearly showing the difference between baseline US images and images at endpoint. Reduced structural changes and no signs of neovascularization but the tendon still have the same size or even slightly thicker than before treatment. In figure 6.3.1, the corresponding images of a case treated with US/CD guided arthroscopic shaving shows the same situation when it comes to structure and neovascularization but a clear change towards a thinner tendon. Thus, the most important findings of study II were that there were good clinical results, improved tendon structure and decreased neovascularization after both treatments, and decreased tendon thickness after US/CD guided arthroscopic shaving.

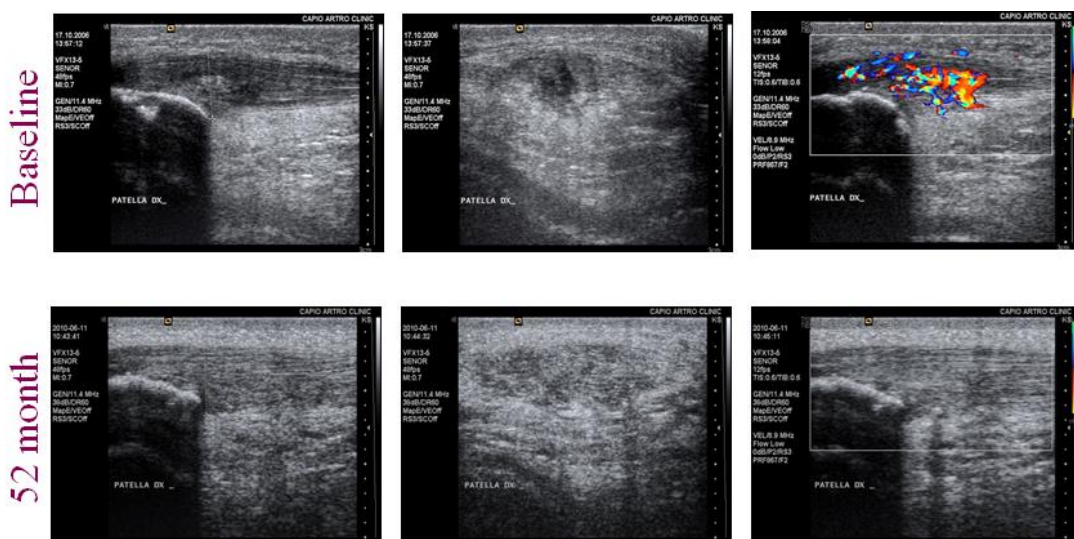


Figure 6.3.0. The PT in a male (35 years) treated with US/CD guided sclerosing injections. US and CD findings at baseline and at endpoint (52 months after intervention). Longitudinal and transversal views (grey-scale US) and longitudinal view (CD).

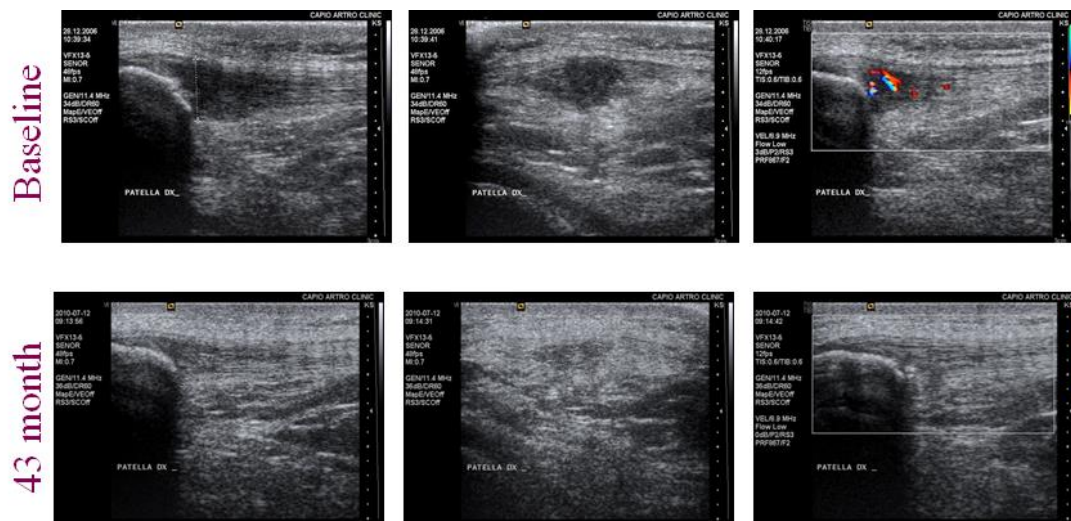


Figure 6.3.1. The PT in a male (30 years) treated with US/CD guided arthroscopic shaving. US and CD findings at baseline and at endpoint (43 months after surgery). Longitudinal and transversal views (grey-scale US) and longitudinal view (CD).

In a former study evaluating CD findings in patients with patellar tendinopathy the authors stated that about two thirds of the patients with jumper's knee can be expected to have structural tendon changes with neovascularization (Hoksrud et al 2008). It is somewhat unclear if the tendons treated were included with the same strict definition of chronic painful impairing patellar tendinopathy that was addressed in study II of this thesis. They concluded that there was no relationship between changes in US characteristics and knee function after sclerosing treatment. The follow up with US/CD examination was performed 12-15 months after the sclerosing treatment, which may be too early to detect changes. Our follow-up in study II was done 3-5 years after treatment.

It should be emphasised that the presence of visible high blood flow inside the tendon alone was not a reason to give another sclerosing injection to the patients in study II, group B. It was important to evaluate the clinical condition accurately at follow-up, since a healing process of a tendon most often involve a great amount of longitudinal high blood flow spread in the whole depth and in a wider part of the tendon than just in the area of hypoechoic changes (Alfredson et al 2006) and at this stage a repeated injection might interfere and break this positive trend.

Treatment of patellar tendinopathy/jumper's knee with sclerosing injections requires multiple injections, on an average three treatments, with at least 6-8 weeks in between. This means a time consuming treatment method compared to the one-stage procedure US/CD-guided arthroscopic shaving. However, in contrast to the results at the one year follow-up, where the surgical method showed better results in all evaluated variables, both treatments seem to reach the same outcome in terms of improved tendon structure, decreased blood flow and self-reported pain during activity (VAS), in the 3-5 years perspective. The one and only remaining difference between the two treatment methods was the decrease in AP-thickness of the tendon, which was shown only in the surgical group. In fact the tendon thickness in the group treated with sclerosing injections increased at the one year follow-up, while 46 months after treatment the AP thickness seems to be back at baseline before treatment. In the surgical group the tendon seems to show a greater improvement getting closer to a "normal" tendon - at endpoint of this study.

To keep in mind; Decisions about treatment should never be based on results from solely diagnostic imaging, no matter how successful. It is always the results from the clinical examination and the history of the disease or disorder that should be considered as "hard currency" (Khan et al 1998a). However using the right kind of imaging modality in an appropriate way might make these decisions easier and more reliable.

In **study III** our ambition was to evaluate the accuracy of office-based US imaging performed by a BT in order to rationalise the care process, concerning patients with disabling and chronic pain of the shoulder.

It appeared likely that small partial “under-surface” ruptures at the insertion of a tendon on the greater or lesser tuberosity (the tendon footprint) could be missed by the surgeon, since the results from US and MRI in several cases were consistent on this diagnose but could not be confirmed during surgery. These ruptures are seldom of clinical importance but the miss-outs could affect the result of the correlation between surgical and imaging findings.

Results from this study clearly show that US is sensitive in detecting FTT but less good in detecting PTT. However, out of 29 PTT, distributed in all three tendons (SSP, ISP and SSC), US correctly identified 17, missed 6 and overrated 7 as being FTT. Most of the false-negative results from the US examinations overestimated the severity of the injuries. A diagnostic modality that produces a high rate of true positive results and an acceptable rate of false negative results can help in avoiding unnecessary surgical interventions (Boenisch et al 2000, de Jesus et al 2009).

The role of diagnostic imaging, when examining patients with shoulder pain, is to guide treatment decisions concerning surgical or non-surgical management. One specific reason to examine patients with symptoms of impingement is to determine whether the rotator cuff is intact or not. Since a partial thickness tear rarely motivates surgical repair the most important task for the diagnostic imaging in these patients is to accurately detect or exclude FTT and CT in the tendons of the rotator cuff. This knowledge helps the surgeon to decide about treatment, but the clinical findings still gives the most essential information (Greenberg 2014). Only the combination of all information allows the surgeon to develop a detailed treatment strategy (Boenisch et al 2000).

Due to additional findings in this study, concerning the diagnostic time-frame of the painful shoulder, we suggest to take into consideration that US, combined with the clinical examination should be the first choice of the diagnostic method instead of MRI. This would be less time-consuming for the patient and probably more cost-effective to the healthcare system.

In **study IV**, the pilot study, we present results from a very short clinical and sonographic follow-up period (mean 6 months) after the start of the treatment, and longer-term follow-ups might show different results. However, our ambition was to find a treatment method that can achieve a fast recovery from this chronic disabling tendon disorder. Careful “scraping” outside the ventral part of the AT significantly reduced the tendon pain and improved the result of the functionality score (VISA-A) in the short-term perspective.

No significant differences in the qualitative US values, such as structural changes or amount of visible blood flow, could be found at 6 months compared to the values before the start of the treatment. However, in conformity with results from **study II**, evaluating the ultrasound findings after treatment of patellar tendinopathy with sclerosing injections or arthroscopic shaving (Sunding et al 2015), the anteroposterior thickness of the tendon treated with sclerosing injections had increased at the short term follow-up, but not the tendon treated surgically.

Studies comparing different treatment methods for chronic painful Achilles- or patellar tendinopathy are often evaluating the results from a treatment in combination with ECC, for example surgery/ECC, shockwave/ECC or injections/ECC. Most often an ECC program is instituted before or after the start of the treatment, or both. In **study IV** the patients in the groups treated with surgery or sclerosing injections were instructed to slowly return to full loading activity, starting two weeks after a treatment session. However, it was emphasized that they should avoid the specific ECC program. The short-term results presented in this study imply that the ECC program might pose a major tribute to the excellent results of those other treatment methods, in former studies.

Good clinical results in a faster and more tolerable way were seen in both **study II** and **study IV** in the groups treated with US/CD-guided surgical methods (arthroscopic shaving of proximal PT or mini-invasive scraping of midportion AT). The resemblance between those treatment methods is that the tendon tissue is left untouched and the procedure is focusing on destroying the transversally in growing blood vessels at the deep surface of the tendon.

6.4 CORRELATION US FINDINGS VS CLINICAL SYMPTOMS

Until today no convincing results have been presented concerning the correlation between symptoms, clinical findings, and US/CD findings in tendon disorders/tendinopathy despite a lot of research performed in the area. It is getting more and more obvious that it is not a linear relationship – at least not when it comes to tendon thickness and the amount of neovascularization. For example - when coming to tendon thickness, it seems that, at an early stage of the tendinosis the thickening is shown in just a local area, and when the tendon starts to heal it gets thick in a wider/longer part. This phase is also very troublesome for the patient because the stiffness and some deep pain at the start of loading, before getting warm, is sometimes worse but the sharp disabling pain has often faded away at this stage and later on, the structural changes and the tendon thickness will gradually go back to “normal”. However, this may take several years after the symptoms have disappeared.

When looking at the amount of neovascularization, it is partly corresponding to the thickness. The higher visible blood flow the more swelling of the tendon. In the primary phase of the tendinosis, the vessels are seen mostly in a local deep part of the tendon and crosswise to the tendon fibres. Later on, by itself or as a result of treatment, the longitudinal intratendinous vessels seem to be activated and we can see an increasing amount of longitudinal vessels in the whole depth of the tendon. When the most active phase of healing has passed we will see lesser and lesser of the vessels.

There are studies declaring that there is no correlation between sonographic abnormalities and pain in a chronic painful tendon with tendinotic changes on US (Peers et al 2003, Boesen et al 2012). However, Cook et al found that the presence of neovascularization in abnormal patellar tendons was associated with increased tendon pain compared with abnormal tendons without neovascularization (Cook et al 2004). Malliaras and co-workers identified a transition between normal, diffusely thickened tendons and those containing a hypoechoic region. They suggested that these greyscale US changes may represent different phases of tendon pathology and that tendons containing a hypoechoic region are more likely to be painful and contain Doppler flow than diffusely thickened tendons (Malliaras et al 2010).

In **study I** samples for both AT and PT were well balanced in terms of age and gender between symptomatic and asymptomatic tendons but not when it comes to sonographic findings. In some of the knees with clinically diagnosed patellar tendinopathy, no sonographic pathology, neither structural changes nor neovascularization were found.

In **study II** (Sunding et al 2015) evaluating medium-term results after two different US/CD-guided treatments of patients with clinically and sonographically diagnosed patellar tendinopathy, a correlation between the amount of neovascularization and VAS for pain in activity ($r=0.63$ $p<0.01$) as well as between the extent of structural changes and VAS for pain in activity ($r=0.52$ $p<0.0001$), was found and is further investigated in an on-going study. The primary outcome of this study concerns the US/CD findings in the tendon (after treatment) and we found VAS to be an appropriate instrument when calculating the correlation between pain during activity or at rest and satisfaction with treatment. We are aware of the relatively small groups, but when calculating the correlation coefficient we used the data at all follow-up occasions, which gave us a rather large material to minimize the risk of a type II error. Of course there is a need for larger and long-term studies in order to evaluate possible tendon changes, blood flow and correlation to pain during activity and results of treatment, especially since the results in this study are somewhat contradictory to some former studies in this area (Hoksrud et al 2008, Larsson et al 2012).

Over time, the blood flow was the first and quickest parameter to change (a decrease from high to low) in the surgical group. Furthermore, we found that the neovascularization had a strong correlation with patient satisfaction and pain during tendon loading activity, where high blood flow correlated to low patient satisfaction and high score for pain during activity. Tendon thickness was found to correlate to pain at rest, the larger the tendon thickness the higher score for pain at rest.

6.5 SONOGRAPHY - BY WHOM?

US-diagnostics demand patience and physical endurance by the patient as well as the examiner but when looking at the procedure in its whole, it is much more effective than for example MRI and computed tomography (CT), both in terms of time and resources. However, the effectiveness and simplicity of US imaging is sometimes overstated or exaggerated. “Just throw the probe on - and everything will be solved in a second”. Don’t believe it! The most difficult part of ultrasonography is not to perform good imaging but rather to correctly interpret the image findings (Bianchi et al 2007). Even though being highly experienced in using diagnostic US it is good to be humble about the task when starting to perform examinations in a new diagnostic area. It usually takes a lot of time to recognise the features and characteristics of a “new” tissue, diagnose or finding. Knowledge in basic anatomy is essential but not always enough. Interactivity with an experienced clinician is recommended, preferably from a surgical speciality. An experienced surgeon usually knows what to expect in terms of variety of a normal tissue and anatomy, which is hard to learn from an anatomical atlas. To just describe everything you see seldom helps the clinician, to interpret the findings and recognize the “true” pathology is the most important task when working with US.

The fast development of the US technique during the last 10 years has resulted in lower manufacturing costs of less bulky and portable US-machines. Consequently, the machines have become less expensive, making them affordable to smaller health care establishment, outside the regular hospitals and the physiological and radiologic departments. Today, other medical professionals than radiologists, such as orthopaedic surgeons, physiotherapists and other health care personnel, are using US for diagnostic imaging of the musculoskeletal system. However, it is also spreading to eyes and hands without basic education and good training in the art and physics of sonography. Since US imaging is considered to be more user-dependent than conventional radiography or MRI this change in procedure has been up for debate whether it is good or bad.

One drawback often mentioned about US examinations is the dependence of technical skill and the experience of the operator, and the learning curve is known to be long and time consuming (Fessell et al 1998, Jacobson 2002, Robinson 2009).

It requires a lot of time and concentration to become effective and skilful in the use of diagnostic US. Some clinics have seen advantages with a close collaboration between a specialized sonographer with knowledge in US physics, including limitations and pitfalls of the method and the clinician e.g. an orthopaedic surgeon and/or physiotherapist - with knowledge in practical anatomy and injury mechanisms. Teamwork of this kind makes the workflow less vulnerable and interdisciplinary communication inside the team increases the competence of the whole group. Orthopaedics, sports medicine doctors and physiotherapists who wants to concentrate on developing and improve their clinical competence but at the same time realize the advantage of using US in their daily work should consider engaging US-specialists in the team. In some countries special “ultrasound technicians” or “medical sonographers” are educated to perform US imaging in different diagnostic areas. In Sweden a BT educated in the field of clinical physiology and specialised in US imaging, could be a well-chosen co-worker. BTs are one of few professionals in Sweden that acquire university credits, specifically for education in US physics and diagnostic imaging.

We can see several advantages of a cross-disciplinary, medical teamwork when dealing with musculoskeletal injuries and pain disorders. It offers a more effective way to get the best possible interpretations of the patient status when professionals of different specialities bring their own unique knowledge to the team, e.g. orthopaedic surgeons, physiotherapists and sonographers specialized in musculoskeletal US. A full-time engagement of a sonographer makes it easier and less vulnerable to maintain a high quality US activity at an out-patient clinic, which includes technical support and daily maintenance of the US equipment. It also enhances the documentation of the US examination

6.6 STRENGTHS AND LIMITATIONS

Limitations:

The aim of **study I** was to evaluate the modified Öhberg score. However, one could consider it a limitation that no tool, such as Visual Analogue Scale (VAS) for pain or Victorian Institute of Sport Assessment-Achilles (VISA-A) and Victorian Institute of Sport Assessment-Patella (VISA-P) for function, was used to evaluate the clinical severity of the disorders. Therefore, it was impossible to assess the correlation between the severities of sonographic pathology with symptoms in this particular study.

Likewise and unfortunately, no functional score, as the VISA-P, was used for the evaluation in **study II**. However, the VISA-P score was not used at the baseline studies (Willberg et al 2007 and 2011) from which the patients in this follow-up study are included. Instead we thought it was appropriate to evaluate patellar tendon pain during the patients' specific recreational or sports activity together with satisfaction with the results of treatment. Furthermore, when evaluating the clinical outcome of this study we added a single question; "back in full patellar tendon loading activity - yes or no?" Since most other studies on sports-related injuries have used the VISA-P score system (Frohm et al 2004) and SF-36 (Sajovic et al 2011), it would have been better to be able to compare our results of the treatments with the results of studies performed by other authors.

The time interval between MRI of the shoulder and the clinical examination or surgery in **study III** was very long in most cases. This resulted in a significant difference in interval between MRI and surgery compared to the interval between US and surgery. However, this is an obvious limitation due to the true clinical setting and thereby reflecting the reality which also could be considered as a strength of this study. None of the patients had experienced a new traumatic episode in the meantime between MRI and US but progress of less severe injuries could not be ruled out (Mall et al 2010), and this may have put down the results of MRI more than for US. The difference in correlation between US and arthroscopy, compared to the correlation between MRI and arthroscopy might be fully explained by the difference in waiting time between the diagnostic imaging and the clinical examination.

Despite the use of a block-randomization technique – in **study IV** - the groups became unbalanced in terms of gender, due to exclusions and drop-outs, and this resulted in a significant difference in mean length and BMI between the groups at this "half way" interim analyses. Furthermore, the mean duration of pain was significantly lower in group A (ECC) because of some out-layers in the other two groups.

Strengths:

A major strength of the studies of this thesis is that all US and CD examinations were performed by the same US technician and the data were prospectively collected. Furthermore, in **study II** and **study IV** the same orthopaedic surgeon examined all the patients at inclusion and as the responsible physician at each invasive treatment session.

The indications for treatment of Achilles- and patellar tendinosis were held very strict as well as the original treatment methods, i.e. ECC (AT), US/CD-guided sclerosing injections

(PT and AT), US/CD-guided arthroscopic shaving (PT) and US/CD-guided mini-invasive scraping (AT).

In **study III**, the use of surgery as reference method, three experienced shoulder arthroscopists using a standardized protocol and the fact that MRI images were re-evaluated by the same radiologist could be considered as strengths. US imaging was performed blinded from both the clinical and the MRI findings. Moreover, the US examination was performed by a non-radiologist/non-physician, which is uncommon in former studies of this topic, but increasingly often occurring in the out-patient care, especially in connection with physiotherapy. This could be considered to be strength of the study, since it simulates a “real clinical situation”.

6.7 FUTURE RESEARCH AND DEVELOPMENTS

The healing of a tendon from overuse or injury is known to be a slow process (Enwemeka 1989) and this makes it important to find a way to decide not only how to treat, but also when to treat. Our experience, from examining a lot of tendons with US/CD, is that the tendinosis is not necessarily worse because it looks worse. On the contrary, a really swollen tendon with a “firework of blood flow” is probably a tendon that has started its slow way back to normal. This is something we need to consider when we are treating the patient. Should we give another treatment (injections, laser, shockwave ...) or should we just wait and see if the body is capable to take care of the rest? Could it even be that we interfere with the healing process if we repeat our treatment too soon and too often and by that actually extend the time of recovery? These questions need to be addressed in future research. Furthermore, to be able to calculate correlation between pain (VAS), and function (VISA-A, VISA-P), and US/CD findings in future studies we need a reproducible tool to classify sonographic findings, and it would be an advantage if it is relatively easy to use also in a clinical setting.

It is formerly shown in studies for intratendinous injuries or surgery involving cutting in the tendon that the thickness never seems to normalize (Alfredson et al 2009). One can consider the fact that an extra-tendinous procedure gives the tendon a possibility to normalize when looking at tendon thickness, which could promote mini-invasive or arthroscopic surgery guided by US addressing solely the area with neovascularization without touching the tendon. Consequently, it could be interesting to make a long term follow up after ECC to see if the tendon normalizes in AP thickness.

In our studies about treatment of patellar tendinosis/jumper’s knee with US/CD-guided arthroscopic shaving, we found associated intraarticular pathology in 70% of the patients. All patients had an MRI examination prior to surgery reporting “no intraarticular pathology”. The cartilage of the femoral trochlea can be visualized with US, but the sensitivity and specificity is not sufficiently assessed, and to our knowledge a standardized protocol has still not been developed. We plan to perform a study in order to validate the US findings of this area, using arthroscopic surgery as a reference method and also compare the findings with results from MRI.

A long-term follow-up (8-10 years) study in terms of clinical outcome and US findings after sclerosing injections of midportion Achilles tendinopathy (Willberg et al 2008)) is ongoing in our research group.

It would also be interesting to extract more data from the material of this thesis to evaluate the cost-effectiveness and patient satisfaction when comparing US diagnostics and the use of MRI when dealing with patients diagnosed with tendinopathy.

Finally, another area of interest is the continuous development of the US technique and the increasing amount of users. This makes it important to regularly repeat evaluations of validity and reliability of the US imaging technique.

7 CONCLUSIONS

Based on the findings of the present thesis it is concluded that

-with a standardized method for how to measure tendon thickness and set criteriae for evaluating structural changes and amount and distribution of neovascularization, US/CD is a reliable method for evaluating AT and PT.
-the modified, 4-graded Öhberg score showed qualifications to be a useful and reliable instrument when evaluating status and progress of AT and PT disorders.
-when comparing sonographic findings over time we suggest that evaluations are performed by the same sonographer/observer, both in research and in clinical practice, based on a generally high intra-observer reliability.
-in the 3–5-year perspective, a remodelling and a sonographically more normal PT was found after successful treatment with US/CD-guided arthroscopic shaving.
-after treatment with US/CD guided sclerosing injections and arthroscopic shaving of patellar tendinosis/jumper's knee, a correlation between low score for pain during activity, high patient satisfaction and low local blood flow was found. Both treatment methods rendered good and equal clinical results at 46 months. However, patients treated with US/CD guided arthroscopic shaving showed a significantly faster return to sport activity.
-office-based US imaging of the shoulder, performed by a trained biomedical technician, showed a sufficient accuracy in detecting significant rotator cuff tears.
- in terms of identifying rotator cuff tears the diagnostic value of US imaging of the rotator cuff performed in connection to clinical examination was higher than with MRI performed several weeks prior to the examination.
-ECC, US/CD-guided sclerosing injections and US/CD-guided mini-invasive surgery, on chronic painful midportion Achilles tendinosis, showed good clinical results respectively. However, patients treated with ECC reported less pain and were more satisfied with the treatment result, at follow-up 6 months after the start of the treatment.
-US/CD-guided mini-invasive surgery, on chronic painful midportion Achilles tendinosis, showed faster clinical improvement than sclerosing injections and might be a better treatment substitute for patients having difficulties in tolerating the uncompromising eccentric training programme.

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10 APPENDIX 1-5

- 1 US protocol – tendinopathy
- 2 VAS - scales
- 3 VISA-A questionnaire
- 4 Clinical protocol – study IV
- 5 US protocol – rotator cuff



Person nr:

Namn:

Datum:

Sign:

DUPLEX, Patellarsena ☐ / Achillessena ☐

HÖGER:

Dimension (mm): prox:..... mid:..... dist:.....

Strukturförändring:

0: ☐ 1: ☐ 2: ☐ 3: ☐

Kärlinväxt:

0: ☐ 1: ☐ 2: ☐ 3: ☐Behandling (injektion):

Substans:..... Mängd (ml):.....

Effekt (1-3):.....

Skiss

VÄNSTER:

Dimension (mm): prox:..... mid:..... dist:.....

Strukturförändring:

0: ☐ 1: ☐ 2: ☐ 3: ☐

Kärlinväxt:

0: ☐ 1: ☐ 2: ☐ 3: ☐Behandling (injektion):

Substans:..... Mängd (ml):.....

Effekt (1-3):.....

Skiss

Kommentarer:

.....

.....

CD nr:

Ansvarig läkare:.....



Person nr:

Namn:

Datum:

Sign:

Smärtskala för:

Hälsena ☐ / **Knäskålsena** ☐Sätt markering på linjerna för **HÖ (X)** och/eller **VÄ (I)**

0 = ingen smärta och 100 = outhärdlig smärta

Ange den senaste tidens värsta smärta.

VAS

0-----100

Graden av smärta i senan vid vila (obelastat)

0-----100

Graden av smärta i senan vid aktivitet (i belastning)

0-----100

Graden av stelhet i senan

0-----100

Graden av tillfredställelse efter behandling

VISA-A-S FRÅGEFORMULÄR – utvärdering av hälsenebesvär

Namn: _____ Datum: _____ Skadad hälsena: Höger / Vänster

I DETTA FRÅGEFORMULÄR SYFTAR ORDET SMÄRTA SPECIFIKT PÅ SMÄRTA I HÄLSEAN.

1. När Du stiger upp på morgonen, under hur många minuter upplever du då stelhet i hälsenan?

100 min	100 min	90 min	80 min	70 min	60 min	50 min	40 min	30 min	20 min	10 min	0 min	0 min
	0	1	2	3	4	5	6	7	8	9	10	

Poäng

2. När du väl är igång under dagen, har du då smärta när du stretchar hälsenan maximalt över en trappkant? (med sträckt knä)

kraftig/ svår smärta												ingen smärta
	0	1	2	3	4	5	6	7	8	9	10	

Poäng

3. Om du går på plant underlag i 30 minuter, får du då ont i hälsenan inom de närmaste 2 timmarna? (Om du på grund av smärta inte kan gå på plant underlag i 30 minuter, sätt 0 på denna fråga).

kraftig/ svår smärta												ingen smärta
	0	1	2	3	4	5	6	7	8	9	10	

Poäng

4. Får du ont i hälsenan vid normal gång nedför en trappa?

kraftig/ svår smärta												ingen smärta
	0	1	2	3	4	5	6	7	8	9	10	

Poäng

5. Om Du gör 10 tåhävningar (på ett ben) på plant underlag, får du då ont i hälsenan under tiden eller direkt efter?

kraftig/ svår smärta												ingen smärta
	0	1	2	3	4	5	6	7	8	9	10	

Poäng

6. Hur många hopp på ett ben kan du göra utan att få ont i hälsenan?

0											10
	0	1	2	3	4	5	6	7	8	9	10

Poäng

7. Utövar du för närvarande någon idrott eller annan fysisk aktivitet?

- | | | | |
|----|----------------------|--|-------|
| 0 | <input type="text"/> | Inte alls | Poäng |
| 4 | <input type="text"/> | Anpassad/begränsad träning och/eller anpassad/begränsad tävling | |
| 7 | <input type="text"/> | Tränar och/eller tävlar för fullt, men inte på samma nivå som innan hälsenebesvären började. | |
| 10 | <input type="text"/> | Tävlar på samma nivå eller högre nivå som innan hälsenebesvären började. | |

8. Besvara antingen A, B eller C i denna fråga.

- Om du inte har någon smärta under aktivitet som belastar hälsenan, besvara endast **fråga A**.
- Om du har smärta under aktivitet som belastar hälsenan, men smärtan hindrar dig inte från att fullfölja aktiviteten, besvara endast **fråga B**.
- Om du har smärta som hindrar dig från att slutföra aktivitet som belastar hälsenan, besvara endast **fråga C**.

A. Om du inte har någon smärta under aktivitet som belastar hälsenan, hur länge kan du då delta i aktiviteten?

0 min	1-10 min	11-20 min	21-30 min	>30 min	Poäng
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
0	7	14	21	30	

ELLER

B. Om du har smärta under aktivitet som belastar hälsenan, men smärtan hindrar dig inte från att fullfölja aktiviteten, hur länge kan du då delta i aktiviteten?

0 min	1-10 min	11-20 min	21-30 min	>30 min	Poäng
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
0	4	10	14	20	

Eller

C. Om du har smärta som hindrar dig från att slutföra aktivitet som belastar hälsenan, hur länge kan du då delta i aktiviteten?

0 min	1-10 min	11-20 min	21-30 min	>30 min	Poäng
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
0	2	5	7	10	



Person nr:

Namn:

Datum:

Sign:

PATIENTUPPGIFTER**HÖ / VÄ Hälsena****Längd:****Vikt:****Arbete:****Idrott/motionsaktivitet:****Besvärdebut:****Besvärduration (månader):****Tidigare behandling:****Skador:****Sjukdomar:****Allergi:****Aktuell medicinering:****Status:****Palpations ömhet (0 – 3):****Resistens:****Nivå:****Rörlighet:****Diagnos:****Insatt behandling (randomisering):**

Person nr:

Namn:

Datum:

Sign:

ULT Axel sida:

Längd: Vikt:

SUPRASPINATUS

Long axis

Short axis

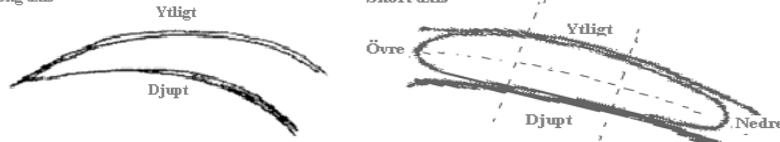
0 ☐ Normal1 ☐ Tendinos☐ Förekalkning

Sentjocklek:mm

2 ☐ Ruptur, partiell ej genomgående → ☐ Djupt (mot led) ☐ Ytligt (mot bursa)3 ☐ Ruptur, partiell genomgående → ☐ Främre ☐ Mitt ☐ Bakre4 ☐ Ruptur, totalMuskulatur: ☐ Ordinär ☐ Hypotrofi ☐ Atrofi**INFRASPINATUS**

Long axis

Short axis

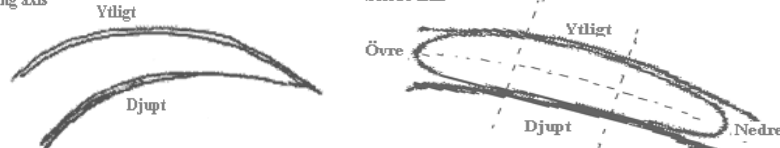
0 ☐ Normal1 ☐ Tendinos☐ Förekalkning

Sentjocklek:mm

2 ☐ Ruptur, partiell ej genomgående → ☐ Djupt (mot led) ☐ Ytligt (mot bursa)3 ☐ Ruptur, partiell genomgående → ☐ Övre ☐ Mitt ☐ Nedre4 ☐ Ruptur, totalMuskulatur: ☐ Ordinär ☐ Hypotrofi ☐ Atrofi**SUBSCAPULARIS**

Long axis

Short axis

0 ☐ Normal1 ☐ Tendinos☐ Förekalkning

Sentjocklek:mm

2 ☐ Ruptur, partiell ej genomgående → ☐ Djupt (mot led) ☐ Ytligt (mot bursa)3 ☐ Ruptur, partiell genomgående → ☐ Övre ☐ Mitt ☐ Nedre4 ☐ Ruptur, totalMuskulatur: ☐ Ordinär ☐ Hypotrofi ☐ Atrofi**AC-Led:** ☐ Normal ☐ Patologisk:**BICEPS:** ☐ Normal ☐ Patologisk:**Subacromial/Subdeltoid bursa:** ☐ Normal ☐ Bursit + + +